# IINR

## ILLINOIS INSTITUTE OF NATURAL RESOURCES



# Modeling the Impacts of Transportation Systems Management on Vehicle Emissions (Phase 1)

Document No. 79/09

DOC. NO. 79/09
April, 1979

# MODELING THE IMPACTS OF TRANSPORTATION SYSTEMS MANAGEMENT ON VEHICLE EMISSIONS
## PHASE I REPORT



Uni ign

Depa ng

F

Frank Beal, Director

Peter Loquercio, Manager
Division of Environmental
Management

State of Illinois
Institute of Natural Resources
309 West Washington Street
Chicago, IL 60606

DOC. NO. 79/09
April, 1979

MODE YSTEMS

by

David E. Boyce
George Provenzano
Frank Southworth
Kristi Cromwell-Cain
and
Kyung S. Chon

Department of Civil Engineering
University of Illinois at Urbana-Champaign
Urbana, Illinois 61801

Department of Civil Engineering
Department of Urban and Regional Planning
Institute for Environmental Studies

PROJECT OFFICER: William J. Murphy
Project No. 60.045

Frank Beal, Director

Peter Loquercio, Manager
Division of Environmental
Management

State of Illinois
Institute of Natural Resources
309 West Washington Street
Chicago, IL 60606

NOTE

This report has been reviewed by the Institute of Natural Resources and approved for publication. Views expressed are those of the contractor and do not necessarily reflect the position of the IINR.

Printed by Authority of the State of Illinois

Date Printed: April, 1979
Quantity Printed: 300

This document has been cataloged as follows:

Boyce, David, E., et. al.

Modeling the impact of transportation systems management on vehicle emissions phase I report / by David E. Boyce, George Provenzano, Frank Southworth, Kristi Cromwell-Cain, and Kyung S. Chon. -- Chicago : Illinois Institute of Natural Resources, 1978.

119 p. 28 cm. -- (Document No. 79/09)

1. Transportation systems management. 2. Motor vehicle emission - Chicago. 3. National Ambient Air Quality Standards - Chicago. 4. State Implementation Plan - Chicago. 5. Highways - Chicago. 6. Chicago Areas Transportation Study. 7. Transportation Control - Chicago. 8. Non-Attainment Areas - Chicago. I. Title. II. Cromwell-Cain, Kristi, III. Provenzano, George. IV. Southworth, Frank. V. Murphy, William. VI. Illinois Institute of Natural Resources, Division of Environmental Management.

IINR Environmental Information Center

Illinois Institute of Natural Resources
309 West Washington Street
Chicago, IL 60606
(312) 793-3870

# PREFACE

This research was undertaken by an interdisciplinary group of faculty and graduate students with backgrounds in urban transportation and environmental analysis. Each member of the team contributed to discussions on all aspects of the report. Certain chapters were the primary responsibility of the individuals indicated below. Dr. George Provenzano, Assistant Professor, Institute for Environmental Studies, was primarily responsible for Chapters 2, 3 and 5. Dr. Frank Southworth, Assistant Professor, Department of Civil Engineering, contributed to Chapters 3, 4 and 6. Ms. Kristi Cromwell-Cain assembled and wrote Chapter 4, and edited and produced the entire report under the supervision of Professor Provenzano. Dr. David E. Boyce, Professor, and Kyung S. Chon, Research Assistant, in the Department of Civil Engineering, wrote Chapters 6 and 7.

The research team wishes to express their thanks to William Murphy, Illinois Institute of Natural Resources, for his interest and critical comments throughout this phase of the research. Frank Sherman and Dennis Kirshner, Illinois Environmental Protection Agency provided numerous comments and advice throughout the project. The staff of the Chicago Area Transportation Study, especially Arnold Rosenbluh and Ronald Eash, patiently provided answers to an ongoing list

of questions concerning CATS' modeling systems. These and other members of CATS' staff provided numerous insightful comments and criticisms on earlier drafts of the report for which we are greatful.

Readers of this report are encouraged to send comments, criticisms, and additional information to me at the address shown on the title page.

Urbana, Illinois — David E. Boyce

December, 1978 — Principal Investigator

TABLE OF CONTENTS

FIGURES

TABLES

## SUMMARY

The Clean Air Act Amendments of 1977 require the Illinois Environmental Protection Agency (IEPA) and local transportation planning agencies to implement short-range transportation system management (TSM) strategies in order to reduce motor vehicle emissions in urban areas which have not attained national ambient air quality standards for carbon monoxide and photochemical oxidants. Many large metropolitan areas, such as the Chicago metropolitan region, have carbon monoxide and photochemical oxidant problems and will not be able to rely solely on stationary source and new motor vehicle emissions controls to meet air quality health standards by the 1982 Clean Air Act deadline. These areas may receive a five year extension to 1987, providing that the states demonstrate in their 1979 state implementation plans that all reasonable transportation control measures are being considered for implementation in meeting the ambient standards.

Joint U.S. Environmental Protection Agency (USEPA) and U.S. Department of Transportation (USDOT) guidelines for the transportation system elements of state implementation plans require IEPA to utilize existing transportation planning processes, for example, those used by the Chicago Area Transportation Study (CATS), in developing a program of transportation controls. These controls must provide for

incremental reductions in transportation system emissions as expeditiously as practicable. The guidelines stress implementation of all reasonable available control measures, but particularly those that can be planned and implemented by 1982 or within the following five years. To this end, local transportation planning agencies must consider a wide variety of the so-called short-range, low-capital TSM strategies, e.g., mass transit improvements, preferential bus and carpool lanes, parking management, pricing, auto-restricted zones, and so on.

In order to evaluate the motor vehicle emissions reduction potential of different TSM strategies in the Chicago metropolitan region, the Illinois Institute for Natural Resources (IINR) in cooperation with CATS requested a three phase study of transportation modeling needs for assessing the impacts of TSM strategies on vehicle emissions. This report contains the results of Phase I and the recommendations for Phases II and III.

In Phase I the literature on the impact of TSM on travel in cities in the United States and other countries was surveyed in order to qualitatively analyze their potential effectiveness in reducing motor vehicle emissions. Some 13 potential TSM strategy sets were analyzed in this manner; in addition to emission reduction potential, each strategy set was analyzed with respect to its public acceptability, implementation feasibility, and modeling capability. Based

1 2 3 4 PART COM 7 4 2 1 7 4 2 1 7 4 2 1
AUTHOR K2733★C

CALL NO. DOCS

AUTHOR

RUSH

TITLE

Modeling the impacts of transportation systems management on vehicle emissions (Phase 1)

DATE ORDERED

OF

SERIES Document No. 79/09

COST

UNIVERSITY OF ILL. LIB.

FUND

DATE OF BILL

EDITION

PLACE Chicago

PUBLISHER Illinois Institue of Natural resources

DATE PUB. 1979

VOLS.

NO. OF COPS.

PRICE

STAMP LOCATION ☐
CIRC. CHARGE ☐
GEN. LIB. STACKS ☐
OFFICE COLLECTION (SEE LOCATION OVER) ☐
DO NOT CAT. ☐

CHARGED TO

FUND

RECOMMENDED BY

APPROVED BY

DATE FWD.

AU =

CITE BIBLOG. REFERENCE ON VERSO

5375764

on these four criteria, each strategy was given a joint ranking. These rankings provided the basis for recommending subsequent modeling work and evaluation--to be carried out in Phases II and III--on strategies which may be promising for the Chicago metropolitan area.

With respect to vehicle emissions reduction potential, it was determined that many individual TSM measures are likely to have negligible impacts, but suitable combinations of such measures might offer moderate to significant emissions reductions. It was noted that several congestion-oriented TSM strategies will reduce emissions only along major traffic corridors. In addition, some area-specific TSM schemes that reduce emissions at specific locations or times of day may well result in increased emissions at other locations and times. Finally, those TSM schemes which offer the greatest potential for emissions reduction tend to be the least acceptable by the public.

On the basis of this analysis it is recommended that Phase II of the research should determine the modeling needs for quantitatively assessing the emissions reduction potential of traffic operations and traffic signalization improvements, commercial vehicle controls, route diversion tactics, and transit operations and management improvements. Phase III should determine the modeling needs for roadway assignment tactics, intermodal coordination schemes, paratransit programs, parking management tactics, and

pricing schemes. Phases II and III will be completed concurrently.

# CHAPTER 1

# INTRODUCTION

Improving air quality in the six-county Chicago metropolitan region continues to be a primary goal of the State of Illinois Environmental Protection Agency and Chicago region's transportation and environmental planning agencies. Although Chicago regional air quality has improved in recent years (20) the U.S. Environmental Protection Agency (USEPA) has designated several parts of the metropolitan region as nonattainment areas with respect to the major motor vehicle related pollutants, nitrogen oxides, photochemical oxidants, and carbon monoxide (44, pp. 8962-9039). Based on 1976 air quality data, annual average airborne concentrations of these pollutants in the Chicago region remain above the national ambient primary and secondary air quality standards for protecting public health and welfare.

Although the use of new model cars, which are equipped with advanced emissions control systems, will bring about further reductions in regional motor vehicle emissions, these improvements alone will not be sufficient to allow compliance with the 1982 Clean Air Act deadline for meeting national ambient air quality standards. Chicago and other major metropolitan areas which face this dilemma may receive a five-year extension to 1987, providing that states

implement all reasonable measures for controlling emissions from vehicles that are currently on the road. In this regard, states must implement motor vehicle inspection and maintenance programs and short-term transportation systems management (TSM) programs which reduce emissions by altering the amount and pattern of motor vehicle travel.

The Illinois Institute for Natural Resources (IINR), formerly the Illinois Institute for Environmental Quality, in cooperation with the Chicago Area Transportation Study (CATS) asked the University of Illinois at Urbana-Champaign to assist with the development, testing, and implementation of methods for evaluating the emissions reduction potential of alternative TSM strategies. These methods will build and augment the present capability of CATS to predict the air quality impacts of long-range transportation plans and programs for the Chicago region.

It is not the intent of this research to develop novel approaches to either travel demand or vehicle emissions modeling. Rather, the most appropriate and currently available travel demand models and vehicle emissions estimation methods, which have undergone testing or have been used elsewhere, will be evaluated for use in the Chicago region. This research should result in specific improvements in CATS' transportation demand modeling capabilities, especially in the areas of modal choice, route assignment, estimation of average highway speeds, and

characterization of peak-period travel demand. In addition, the transportation modeling improvements will be coupled with USEPA's updated mobile source emissions estimation techniques in order to give CATS the capability of assessing the emissions-reduction impacts potential of various transportation system control measures.

The methods developed in this research will enable CATS to undertake more thorough studies of regional travel and emissions impacts of various combinations of proposed TSM control measures. These methods will enable CATS, in cooperation with other regional transportation and environmental planning agencies, to meet state and federal requirements in programming and implementing TSM improvements. In particular, these methods will be useful to CATS for modifying relevent sections of the Illinois State Implementation Plan as required by USEPA.

During Phase I of the research, the potential emissions reduction impacts of TSM strategies were analyzed in a qualitative manner. To quantify the emissions reduction potential of combinations of TSM strategies, transportation planners must resort to the use of transportation models. Therefore, the implications of modeling these TSM strategies were also examined in some considerable detail in relation to CATS transportation modeling capabilities. The findings of this analysis form the contents of this Phase I report.

In the course of the Phase I review and analysis, several agencies and organizations were asked to provide information and to comment on the proposed research for Phase II and III. These included:

1. Office of Transportation and Land Use Planning, U.S. Environmental Protection Agency, Washington,D.C.,
2. Urban Planning Division, Federal Highway Administration, Washington,D.C.,
3. Office of Policy and Program Development, and Office of Planning, Urban Mass Transportation Administration, Washington, D.C.,
4. Office of Environment and Safety, U. S. Department of Transportation, Washington, D.C.,
5. Metropolitan Washington Council of Governments, Washington, D.C.,
6. Bay Area Metropolitan Transportation Commission, Berkeley, California,
7. Southern California Association of Governments, Los Angeles, California,
8. Planning and Research Bureau, New York State Department of Transportation, Albany, New York,
9. Peat, Marwick and Mitchell and Co., Washington, D.C.,
10. Charles River Associates, Cambridge, Massachusetts,
11. System Design Concepts, Inc., Washington, D.C., and
12. Department of City and Regional Planning, Harvard University, Cambridge, Massachusetts.

In addition, a number of other individuals were contacted informally for suggestions.

## Organization of this Report

Following this introduction, the report is organized into six chapters. Chapter 2 contains a summary of the status of the Chicago region with respect to attainment of federal ambient air quality standards. Chapter 3 contains a framework for classifying TSM actions into 13 strategy sets. Current plans to implement these strategies within the Chicago metropolitan area are also discussed.

Chapter 4 includes a synthesis of an extensive literature review of the travel related impacts of the above TSM strategies as observed in major metropolitan areas. Based on this synthesis, a qualitative assessment of the emissions-reduction potential of each TSM strategy set is also presented. In Chapter 5 the general feasibility of implementing each strategy from a technical and public acceptability perspective is considered. The implications of modeling each strategy set in the context of CATS modeling systems is considered in Chapter 6. The recommendations in Chapters 4, 5 and 6 are synthesized in Chapter 7 in the form of recommendations for Phases II and III of the research.

# CHAPTER 2

## STATUS OF THE CHICAGO REGION WITH RESPECT TO AIR QUALITY ATTAINMENT

The USEPA, pursuant to Section 107 (d) (1) of the Clean Air Act Amendments of 1977, has designated areas of the State of Illinois as attainment areas, nonattainment areas, or unclassified areas with respect to the national ambient air quality standards (44, pp. 8962-9059).

The State of Illinois, in making its recommendations to USEPA relied principally on air quality monitoring data from the calendar year 1976. Other information was considered, including a statewide emissions inventory, density data, monitoring site information, and special modeling. The nonattainment area designations were made for five criteria pollutants for geo-political areas.

Several portions of the six-county Chicago metropolitan region (Cook, DuPage, Kane, Lake, McHenry, and Will counties) are nonattainment areas with respect to motor vehicle related air pollutants. For nitrogen dioxide, the Chicago central core area in Cook County, bounded on the north and west by Wacker Drive, on the east by Michigan Avenue, and on the south by Harrison Street (Figure 1) is a nonattainment area. All other areas in the region are designated as attainment areas.

For photochemical oxidants, five counties, Cook, DuPage, Lake, McHenry, and Will, are designated nonattainment areas. Illinois EPA recommended that the remaining counties in Air Quality Control Region 67 (Boone, Grundy, Kane, and Kendall counties) also be included in the nonattainment designation because of their geographic location in a major urban center.

For carbon monoxide, Cook County nonattainment areas include:

1. The Edens Expressway corridor from I-94 to the Kennedy Expressway,

2. The Kennedy, Eisenhower, and Stevenson Expressway corridors from their respective junctions with the Tri-State Tollway to the central business district,

3. The Dan Ryan Expressway corridor from the I-57 Calumet Expressway junction to the Eisenhower Expressway (Figure 2),

4. A central core area bounded on the north by Lake Street and Wacker Drive, on the east by Lake Shore Drive, on the south by Roosevelt Road, and on the west by Halsted Street (Figure 3),

5. An area at the junction of the Kennedy and Edens Expressways, bounded on the north by Lawrence Avenue, on the east by Kenton Street, on the south by Montrose Avenue, and on the west by Cicero Avenue (Figure 4).

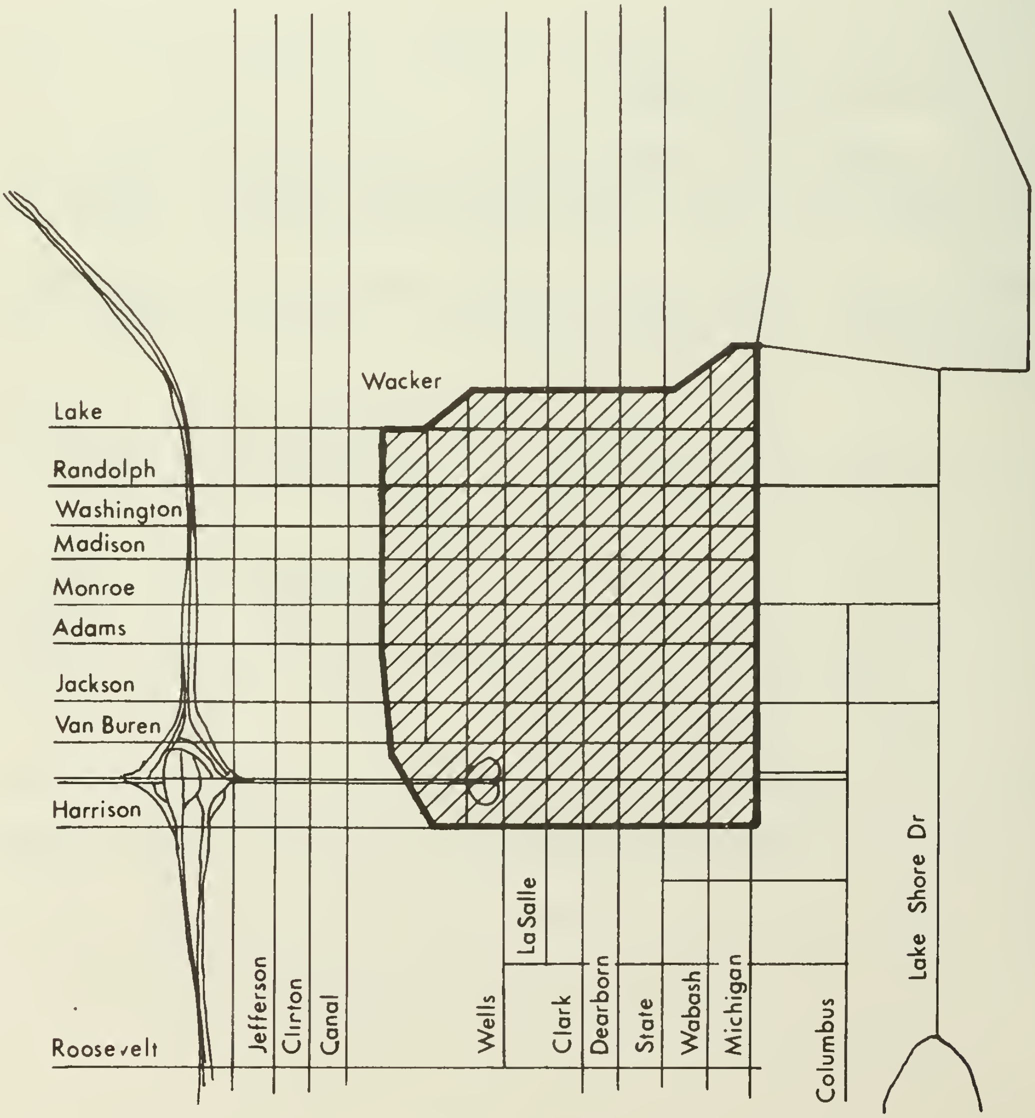
The remainder of Cook County and certain townships in DuPage, Kane, Lake and Will Counties are unclassified (Table 1).

Figure 1

Nitrogen Dioxide Nonattainment

in the

Chicago Loop



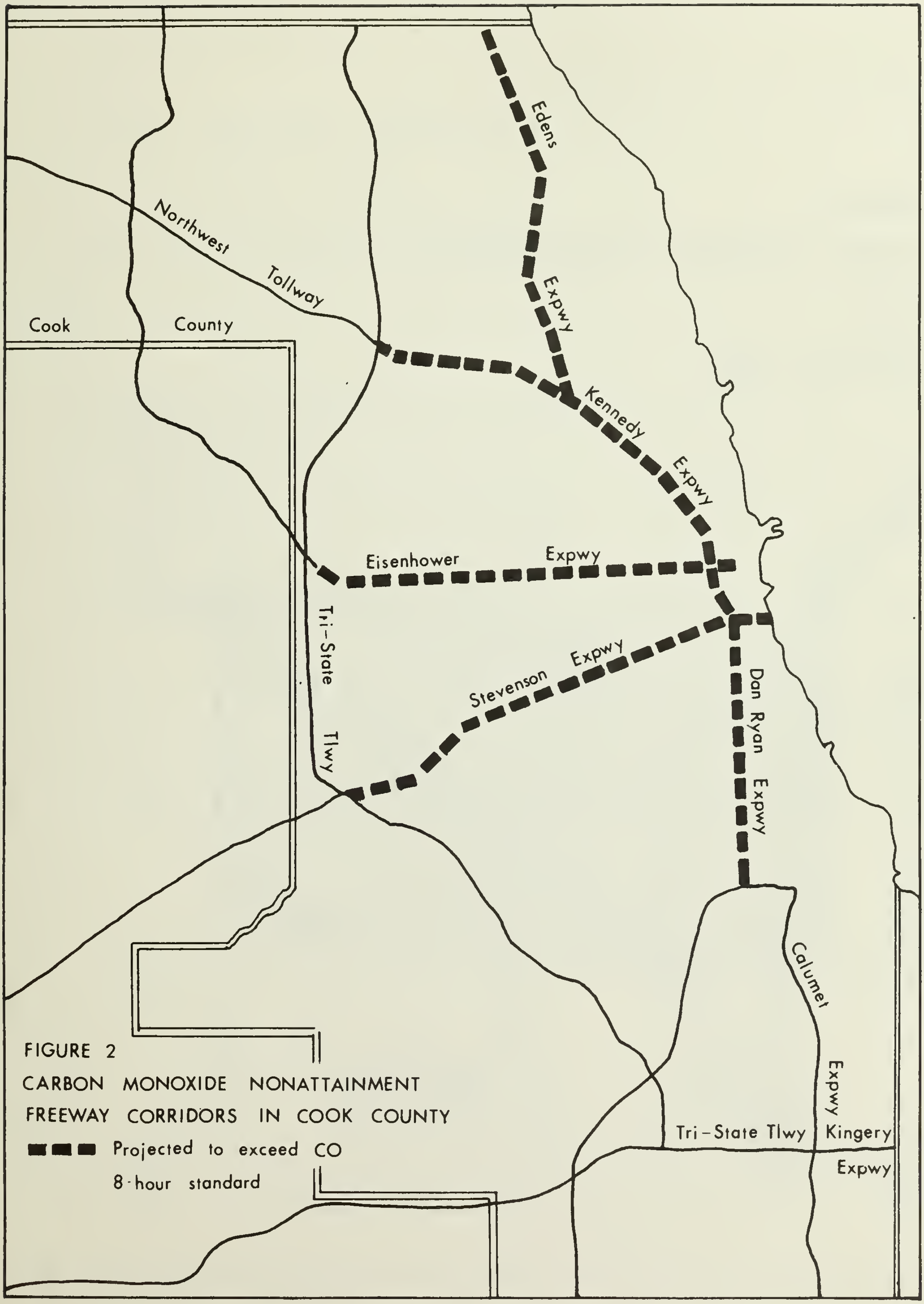



FIGURE 2
CARBON MONOXIDE NONATTAINMENT
FREEWAY CORRIDORS IN COOK COUNTY
Projected to exceed CO 8-hour standard

Figure 3

Carbon Monoxide Nonattainment

in the

Chicago Loop

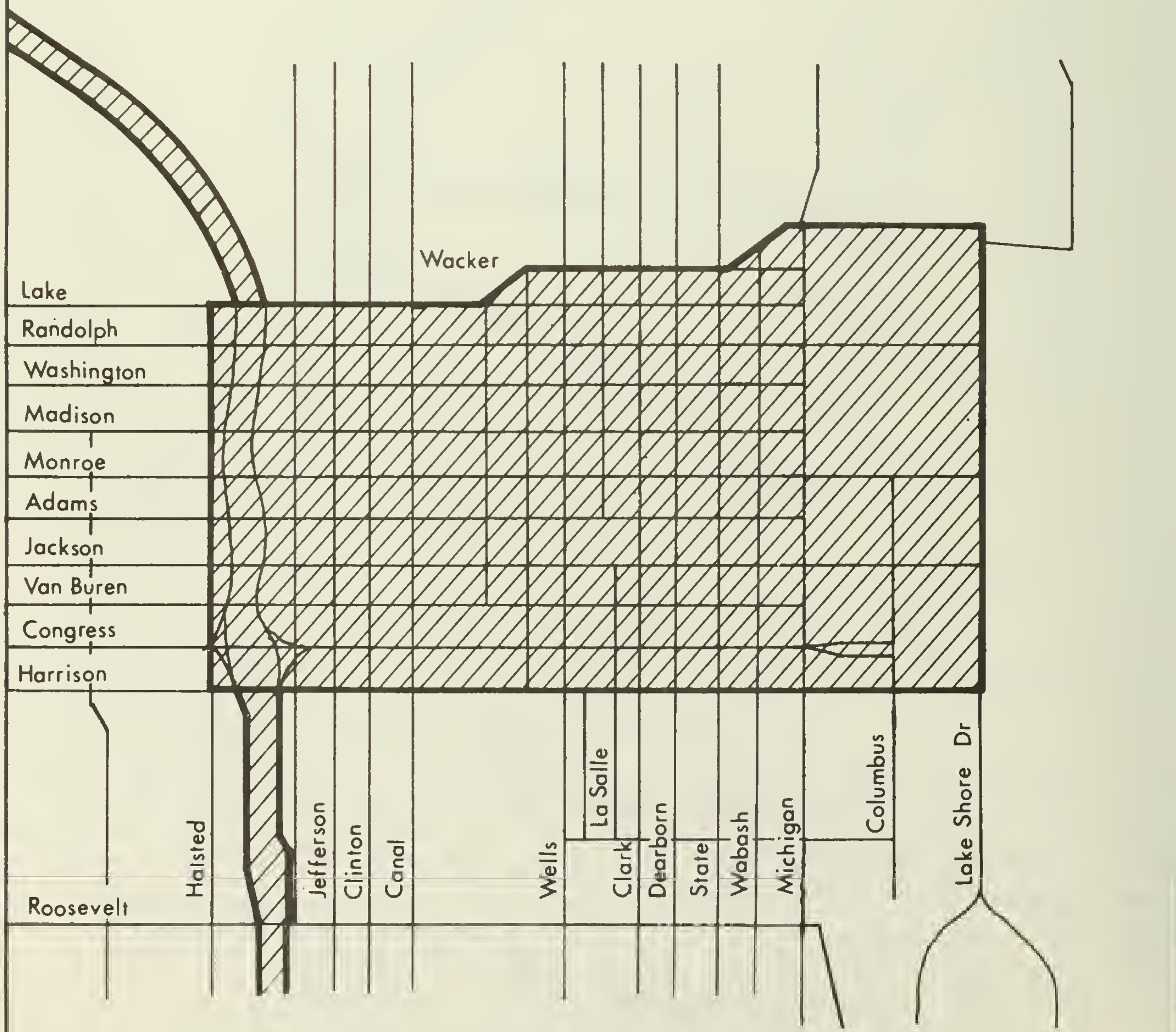


Figure 4

Carbon Monoxide Nonattainment at the junction of the Edens and Kennedy Expressways

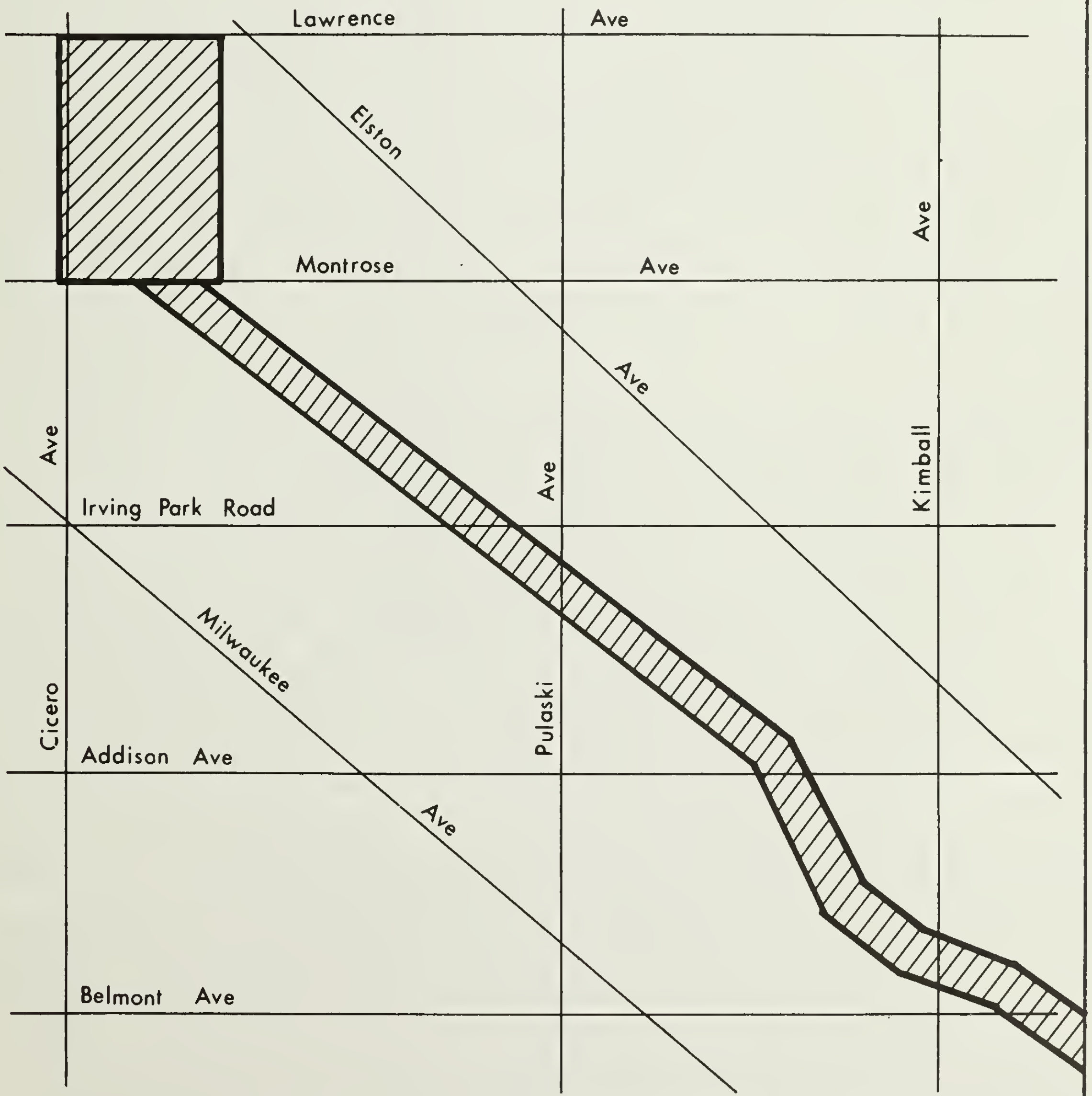


TABLE 1

TOWNSHIPS DESIGNATED AS UNCLASSIFIED

WITH RESPECT TO CARBON MONOXIDE

- Cook County
    - All Townships except for Nonattainment Areas
- DuPage County
    - Bloomingdale
    - Addison
    - Milton
    - York
    - Naperville
    - Lisle
    - Downers Grove
- Kane County
    - Dundee
    - Elgin
    - St. Charles
    - Geneva
    - Batavia
    - ora
- Lake County
    - Deerfield
    - West Deerfield
    - Shields
    - Waukegan
    - Warren
    - Cuba
    - Libertyville
- Will County
    - Joliet
    - Lockport

# CHAPTER 3

# DESCRIPTION OF TSM TACTICS AND REVIEW OF CURRENT IMPLEMENTATION EFFORTS IN THE CHICAGO METROPOLITAN REGION

Presented in this section is a brief description of 59 individual TSM tactics and a review of current efforts to implement these tactics in the Chicago metropolitan region. In the following discussion these tactics have been arranged into 13 strategy sets in order to facilitate an in depth analysis of their potential for improving air quality. Although the set of 59 tactics may not include all potential TSM possibilities, it does represent the large majority of TSM actions which are likely to be used in improving air quality.

The recently published Transportation System Management Plan for Northeastern Illinois (8) reports that in 1977 transportation providers in the six-county region implemented many successful projects which can be categorized as TSM actions. In addition, the plan indicates that during 1978 many more TSM projects will be initiated in the region. In the plan, these projects were grouped according to the four major TSM strategy classifications suggested in the original TSM regulations published in the Federal Register (1975, p. 4297). These include:

1. actions to ensure the efficient use of existing road space,

2. actions to reduce vehicle use in congested areas,

3. actions to improve transit service, and

4. actions to increase internal transit and road management efficiency.

In Table 2 the thirteen strategy sets used in this report are rearranged to reflect the CATS TSM organizational scheme (8, pp. 91-92).

## Traffic Operations

1. Intersection and Roadway Widening. This tactic consists of making intersection improvements for arterials that are heavily congested during the peak hours. It includes widening approaches, adding turn lanes, and making necessary changes in signs and pavement markings. Right-of-way must be acquired in making these improvements.

2. One-Way Streets. This tactic involves changing several existing two-way streets to one way operation in the central business district. Typically, these directional changes must be made for 20-block (approximately one mile) lengths in order to be effective. The tactic includes making necessary changes in signs, signals, pavement markings, bus stop locations, and parking regulations. No major construction or new right-of-way is needed.

TABLE 2

Relation Between CATS TSM Categories and Phase I Strategy Sets

| | CATS' TSM Categories | Phase I 13 Different Strategy Sets |
|---|---|---|
| A. | Actions to Ensure the Efficient Use of Existing Road Space<br>Traffic operations improvements<br>Preferential treatment for transit and other high occupancy vehicles<br>Provision for pedestrians and bicycles<br>Management and control of parking<br>Changes in work schedules and fare structure to reduce peak-period travel | Traffic Operation<br>Traffic Signalization<br>Work Schedules<br>Pedestrians and Bicycle<br>Roadway Assignment<br>Parking Management |
| B. | Actions to Reduce Vehicle Use in Congested Areas<br>Encouragement of carpooling and other forms of riding sharing<br>Diversion, exclusion and metering of automobile access to specific areas<br>Auto licenses, parking surcharges and other forms of congestion pricing<br>Establishment of car-free zones and closure of selected streets to vehicle traffic or through traffic<br>Restrictions on downtown truck delivery during peak hours | Commercial Vehicles<br>Route Diversion<br>Pricing |
| C. | Actions to Improve Transit Service<br>Provision of better collection, distribution and internal circulation services within low-density areas<br>Greater flexibility and responsiveness in routing, scheduling and dispatching of transit vehicles<br>Provision of express bus services in coordination with local collection and distribution services<br>Provision of park-and-ride services from fringe andtransportation corridor parking areas<br>Provision of shuttle transit services from CBD fringe parking areas to downtown activity centers<br>Encouragement of jitneys and other paratransit services<br>Simplified fare collection systems and policies<br>Provision of shelters and other passenger amenities<br>Better passenger information systems and services | Transit Operations<br>Intermodal Coordination<br>Paratransit |
| D. | Actions to Increase Internal Transit and Road Management Efficiency<br>Improved marketing<br>Developing cost accounting and other management tools to improve decision-making<br>Establishing maintenance policies that assure greater equipment reliability<br>Use surveillance and communications technology to develop real time monitoring and control capability | Transit Management |

3. Turn Lane Installation. This tactic includes reconstructing medians to build left-turn lanes along major arterials having peak hour congestion. No new right-of-way is required. Traffic signals, road signs and pavement markings must be changed.

4. Turning Movement-Lane Use Restrictions. This tactic includes peak hour prohibitions on left turns and restrictions on lane use (e.g., right turn only) along major city streets. Traffic signals and road signs must be changed.

5. New Freeway Lane Using Shoulder. This tactic involves narrowing existing freeway lanes from twelve feet to ten feet and narrowing freeway shoulders so that a new, third through-lane can be created through major bottleneck sections. No new right-of-way is needed, but some pavement reconstruction and new lane markings must be made.

Numerous projects to improve traffic operations are implemented in the six-county Chicago metropolitan region each year. These projects typically include widening roadways and improving intersections, channeling and installing turn lanes, and installing appropriate intersection signals (8, p. 96).

Traffic Signalization

1. Signal Controller Improvement. This tactic consists of improving individual intersection operations by changing a fixed time signal to a fully-actuated signal. It includes installing new displays, changing signal timing and phasing, and installing pedestrian signals. No widening or pavement reconstruction would be necessary.

2. Arterial Signal System. This tactic consists of interconnecting traffic signals along several miles of major arterials. It includes installing a new master controller, developing new timing plans and improving signals displays and phasing.

3. Area Signal System. This tactic involves installing a central computer to control the central business district traffic grid and several arterials approaching the central business district. It includes new signal timing and phasing, fire preemption, special events timing, and a monitoring capability.

4. Freeway Diversion and Advisory Signing. This tactic consists of instrumenting freeway segments in order to detect congestion and accidents and to activate signs suggesting alternate routes for approaching traffic.

5. Freeway Surveillance and Control. This tactic consists of instrumenting radial freeways with ramp metering, TV surveillance, incident detection, and incident response capabilities. Ramp metering must be coordinated with parallel street traffic signals.

Each year numerous projects to improve traffic signalization are undertaken throughout the six-county Chicago metropolitan region. These projects include installing new traffic signals at uncontrolled intersections, modernizing existing signals, and marking pavements to convey desired regulations and warnings to motorists (8, p. 78).

## Commercial Vehicles

1. On-Street Loading Zones. This tactic consists of an areawide program to remove parking spaces on CBD streets in order to provide loading zones. The tactic would be accomplished through city ordinances.

2. Off-Street Loading Areas. In this tactic designated areas for loading and unloading are established in alleys or other access facilities. The tactic would be applied on a spot-location basis in the CBD.

3. Prohibit Peak-Hour On-Street Loading. In this tactic regulatory action would ban on-street loading during peak periods in the CBD.

4. Truck Route System. In this tactic designated truck routes would divert truck traffic that is approaching the city around highly congested areas.

Work Schedule Modifications

1. Staggered Work Hours. This tactic involves establishing a cooperative arrangement by major employers to stagger work hours. The metropolitan planning organization would administer this program on a regional basis.

2. Four-Day Week. This tactic involves organizing a cooperative arrangement by employers to establish a four-day work week. The metropolitan planning organization would administer this program on a regional basis.

The Transportation Operations Committee of CATS has organized a Staggered Work Hours Task Force to study the question of dispersing the peak-hour travel demand by spreading out arrival and departure times. The task force will examine those locations in the regions where staggered work hours can impact on congestion. The task force will also review previous work done on the Chicago CBD to see if

it is still valid (8, p. 109). The objective of the task force is ultimately to implement and evaluate a staggered hours demonstration project.

The Northeastern Illinois Planning Commission (NIPC) has also studied the feasibility of instituting a program of staggered work hours. Various employers' practices for altering workday schedules were explored. An analysis of employer survey data was used to examine different variable hour scheduling techniques (8, p. 111).

## Pedestrian and Bicycle Improvements

1. Widen Sidewalks. This tactic consists of widening sidewalks in the major commercial core of the central business district, which reduces roadway width and eliminates some parking. Pedestrian amenities, bus shelters, etc., can be installed.

2. Pedestrian Grade Separation. This tactic consists of constructing pedestrian overpasses or underground walkways to avoid high speed arterials, particularly for school crossings and park entrances. Pedestrian crossings at adjacent signalized intersection must be prohibited.

3. Bikeways. This tactic involves constructing a system of bikeways throughout the city to encourage bicycle use in making worktrips. Bikeways include separate right-of-ways and on-street bike lanes. Some curb parking must be eliminated.

4. Bicycle Storage. This tactic consists of installing bike lockers at major mass and commuter rail terminals in the central business district.

5. Pedestrian Control Barriers. This tactic consists of installing barriers and railings at certain intersections in order to control pedestrian flow, prevent jaywalking and improve traffic flow. It includes new pedestrian signals and phasing for vehicular traffic.

In response to increased demand for bicycle facilities in the Chicago area, a number of projects are underway to create bikeways, designated or constructed, that physically separate bicycle traffic from pedestrian and vehicular traffic. To coordinate regional bikeway network development in the region, NIPC has made an inventory of existing and proposed bikeways and evaluated regional and local plans, ridership statistics and bicycle sales (8, p. 111).

Roadway Assignment

1. Exclusive Bus Lane. In this tactic right curb lanes on major arterials are reserved for buses. Right turns only are permitted during peak hours. A lane for existing traffic and some parking space must be removed from use.

2. Bus Only Street. This tactic consists of changing short street segments in the central business district into bus only streets with corresponding terminal and transfer points. All other traffic, including taxis, would be prohibited from these streets.

3. Contra-flow Bus Lane. In this tactic existing one-way streets in the central business district are changed to allow buses only in the contraflow direction. Some on-street parking must be removed, and some bus stops must be relocated.

4. Reversible Lane System. In this tactic segments of arterial roadways are changed in cross section from two-two with left turn lanes to three-two during peak hours with left turns prohibited. Special bus preferences are not included. Signals must be installed.

5. _Freeway High Occupancy Vehicle Bypass._ In this tactic, special freeway entrance lanes are created to enable high occupancy vehicles to bypass queues of stopped vehicles. If these bypass lanes can be constructed on the freeway shoulder, no right-of-way would be needed.

6. _Exclusive Bus and High Occupancy Vehicle Lane on Freeways._ In this tactic various lengths of the left (median) lane on six-lane freeways are reserved for buses and carpools during peak hours. These special lanes need not be physically separated from the adjacent through lanes.

Several roadway assignment projects are currently being studied and planned for the Chicago area. The Chicago Department of Public Works, CATS, and the Illinois Department of Transportation (IDOT) are investigating alternatives for providing express bus lanes on the Stevenson Expressway to serve the Southwest Corridor (8, p. 110). Three low cost bus service alternatives have been evaluated. These included:

1. exclusive bus lanes installed on the existing shoulder of the Stevenson plus exclusive entrance ramps,
2. exclusive bus lanes installed on the existing shoulder of the Stevenson, and
3. an exclusive bus route constructed along the Illinois Central Gulf Railroad right-of-way.

Because Chicago has existing commuter rail service in all

corridors, except the Southwest Corridor, high occupancy vehicle lanes on the Stevenson Expressway would appear to have great potential for attracting transit ridership in this area of the region.

Planning is also in progress for the implementation by 1978 of contraflow exclusive bus lanes on four streets in the central business district (8, p, 147). All east-west bus routes in the central business district will be shifted to operate on these four streets, resulting in buses being removed from all other east-west streets. Bus travel times will be decreased and service should operate more regularly on these streets. In addition, vehicular flows on streets from which buses are removed will be enhanced and emissions correspondingly reduced.

## Route Diversion

1. Residential Traffic Control. This tactic involves the prohibition of turns from surrounding arterial streets into residential areas during morning and evening peak periods.

2. Area Licensing. This tactic involves restriction of entry into the commercial core of the central business district. Access by private auto would be prohibited to vehicles without appropriate identification indicating that

a fee had been paid. The tactic must be combined with improved transit service.

3. Pedestrian Malls. This tactic consists of closing streets in a two or three block commercial (retail) area to automobiles, taxis and trucks. It involves extending sidewalks, installing transit shelters, and providing peripheral parking. This tactic may require the acquisition of right-of-way for the purpose of closing streets.

4. Auto Restricted Zones. This tactic restricts access of private automobiles to a core area of the central business district during the peak rush hours, but it does permit buses and taxis to enter the restricted zone. This tactic would require improved transit service from peripheral parking areas to the restricted zone.

Construction of the State Street Transit Mall has begun, and when completed, this mall will have one lane of roadway in each direction available for use only by buses and emergency vehicles. The mall will be nine blocks long extending from Wacker Drive to Congress Street (8, p. 114). Based on an analysis of the physical features, functional characteristics, economic characteristics, and other impacts of auto-restricted zones, NIPC has made a set of recommendations on where the potential for successful future auto-restricted zones is greatest and what impacts could be

expected if they are built.

## Transit Operations

1. Bus Route and Schedule Modification. This tactic consists of changing the routing and timing of bus operations in various corridors in order to shorten headways and improve transfer connections. It also includes eliminating buses operating without sufficient economic return.

2. Express Bus Service. In this tactic, buses are run on routes from the suburbs to the central business district with no boarding inbound and no alighting outbound within the city limits (or some other boundary). Express bus service would operate only during peak hours.

3. Bus Traffic Signal Preemption. This tactic consists of installing devices which would allow transit vehicles to change traffic signals to facilitate faster travel, particularly along congested arterials approaching the central business district.

4. Bus Terminals. This tactic consists of installing shelters, benches, and transit schedule and fare information in downtown areas.

5. Simplified Fare Collection. This tactic consists of the implementation of a flat-fare structure along with a uniform region-wide transfer policy for the entire transit system.

There are numerous projects, under way or in the planning stages, which are designed to improve transit and commuter rail operations in the Chicago metropolitan region. A few of these projects are mentioned below as examples of current efforts in this area.

With respect to modifications in bus and commuter-rail routes and schedules in 1977, the Regional Transit Authority (RTA) instituted new off-peak schedules for commuter-rail service in order to achieve greater patronage and equipment utilization in the off-peak and weekend periods (8, p. 115). The Chicago Transit Authority (CTA), in cooperation with regional agencies, the City of Chicago, and area merchants, is studying bus stop locations and bus operations on North Michigan Avenue in order to recommend TSM-type actions for that area (8, p. 117). The RTA, CTA, and other regional transit providers are continuously reviewing current service patterns in order to extend services to new areas, to expand services in areas of high demand, and to eliminate services in areas of declining demand (8, p. 128).

As indicated above, a major study of alternatives for providing express bus service on the Stevenson Expressway is currently underway. Existing express bus service, for example, service to the west side of the downtown, is also being modified to serve larger numbers of commuters more efficiently (8, p. 118).

The CTA and RTA are also improving transit and commuter-rail passenger waiting conditions throughout the region. In 1977, for example, CTA installed 200 bus stop passenger shelters primarily at locations having heavy boarding volumes, wide headways, and exposure to the elements (8, p. 119). In addition to installing bus shelters, the RTA is conducting a systemwide benefit-cost analysis of proposed new stations, rehabilitation of existing stations, and consolidation or closing of some existing stations (8, p. 149).

Finally, actions to simplify fare collections are underway or in the planning stages. A program which would allow employers to sell monthly passes at a discount to their employees is currently in an experimental stage (8, p. 120). The ten-ride, non-discount ticket has been reintroduced by RTA in order to reduce ticket purchase time (8, p. 121). Coin-operated turnstiles, which accept any combination of coins, are being installed at CTA rapid transit stations (CATS 1978, p. 130).

Transit Management

1. Marketing Program. This tactic involves initiating a regional public relations campaign to advertise transit information and to distribute route maps and schedules.

2. Maintenance Improvements. This tactic involves implementing a program to increase the frequency, quality, and scope of transit maintenance in order to improve vehicle reliability, performance, and productivity.

3. Vehicle Fleet Improvement. This tactic includes purchasing new transit vehicles in order to modernize the transit fleet, increase reliability, and reduce maintenance costs.

4. Operations Monitoring Program. This tactic involves using additional field personnel to monitor bus headways and schedule adherence on a system-wide basis.

There are also numerous projects, underway or in the planning stages, which are designed to improve transit and commuter-rail management practices in the Chicago metropolitan area. A few of these projects are cited as examples of current efforts in this area.

With respect to marketing tactics, the Chicago area transit promotional and advertising campaigns have received funding of $2.2 million for the 1978 fiscal year (8, p. 159). The RTA has instituted a program to provide 24-hour travel information about the fastest route possible, carrier schedules and transit costs to callers in the six-county region (8, p. 159). Since 1976, CTA has been publishing bilingual transit maps, fare charts, and other public information (8, 1978, p. 131).

Both CTA and RTA have instituted several maintenance improvement and maintenance management programs. These include:

1. establishment by RTA of regional bus maintenance and storage facilities (8, p. 125),

2. consolidation by RTA of commuter railroad maintenance and yard facilities (8, p. 154),

3. development by RTA of a computer-based spare parts and tire inventory control system (8, p. 156), and

4. a study by CTA to upgrade and replace garages, storage yards and terminal maintenance facilities (8, p. 161).

Both CTA and RTA have programs to upgrade and modernize the transit fleet. RTA's policy in acquiring new rolling stock for commuter-railroads is to standardize equipment whenever possible (8, p. 155). RTA and CTA are also conducting a benefit-cost analysis to determine the optimal usable life-span of buses, locomotives, and coaches (8, p. 149). Finally, CTA and RTA have programs for monitoring and

managing all aspects of their operations, including service, materials and finances.

Intermodal Coordination

1. Park-and-Ride Facilities. This tactic includes the construction of parking lots at bus, rapid transit, and commuter rail stations in outlying locations. Park-and-Ride often requires the purchase of right-of-way and the construction of parking lots, bus bays, shelters, and bus channels.

RTA has undertaken a project to improve commuter access to commuter rail stations. Specific measures that are being taken include providing adequate parking facilities and adequate feeder bus service (8, p. 115).

2. Transfer Improvements. This tactic alters the schedule of buses to insure efficient and perhaps costless transfers to rail service and could include reducing or eliminating transfer costs.

CATS has completed a study of suburban parking facilities. The region's commuter parking inventory was updated and is being summarized for use in analyzing regional parking needs. The analysis will focus on parking needs for new commuter stations (8, p. 108).

The RTA, CTA, and City of Chicago are converting part of the Midway Airport parking lot to a park-and-ride lot with 1300 spaces. This project is being planned in conjunction with other efforts to reduce congestion on the Stevenson Expressway (8, p. 151).

Paratransit

1. Carpool Programs. In this tactic the metropolitan planning organization establishes a regional computer matching program for carpools.

2. Vanpool Programs. This tactic involves large employers financing the purchases of vans for eligible groups of employees.

3. Taxi/Group Ride Programs. This tactic involves changing taxi operating policies and regulations to allow reduced rates for pre-arranged groups.

4. Dial-A-Ride. This tactic involves establishing minibus service for suburban areas.

5. Jitney Service. This tactic consists of providing unscheduled service along fixed routes. The tactic may require new regulation to allow non-transit operators to provide service.

6. Elderly and Handicapped Service. This tactic consists of a special regional subsidy program to enable elderly and handicapped to use taxi services.

The Transportation Operations Committee of CATS has organized a task force to foster the development of vanpools. This task force is actively working with the IINR, Division of Energy, to help interested companies initiate vanpool operations. IINR makes available technical assistance in planning and organization of vanpools. A vanpool matching program has been made operational and is available to interested firms who want to organize vanpool passenger lists (8, p. 113).

NIPC has made an inventory of existing and proposed ridesharing programs in the region. Analysis of the results of the inventory indicates that the potential for regional benefits from ridesharing is quite high (8, p. 114).

The region's transportation providers are examining transportation services for the elderly and handicapped. A study will be performed to increase the efficiency of existing services and facilities, to distribute services more rationally, and to coordinate and integrate service for the elderly with existing transit service as it becomes more accessible for these individuals (8, p. 150).

CTA plans to purchase 20 small specially equipped vehicles to transport elderly and handicapped individuals. These vehicles will be used in a demonstration project

sponsored by CTA and the City of Chicago Department of Public Works (8, p. 152).

Finally, RTA plans to develop and test non-conventional methods of providing transit in low density areas for mobility limited individuals. This project will take place in suburban areas and will emphasize the utilization and coordination of existing resources and services.

<u>Parking Management</u>

1. <u>Curb Parking Restrictions.</u> This tactic consists of eliminating on-street parking for several blocks along major arterials during the morning and evening peak periods.

2. <u>Residential Parking Control.</u> This tactic consists of restricting on-street parking in residential neighborhoods to two-hour periods from 7 a.m. to 7 p.m., except for those vehicles displaying resident parking permits.

3. <u>Off-Street Parking Restrictions.</u> This tactic consists of prohibiting the use of all off-street lots in the commercial area of the central business district until after the morning peak period in order to shift commuters to transit and reserve parking for shoppers.

4. Preferential Rates for High Occupancy Vehicles and Short-Term Parkers. This tactic consists of restructuring parking rates at all lots in the CBD to favor carpool or vanpool vehicles over single occupant vehicles.

5. Preferential Spaces for High Occupancy Vehicles. This tactic consists of reserving the most convenient spaces in parking lots for carpool or vanpool vehicles. It would be applied in large employment complexes having very large parking lots.

CATS has studied the problem of parking congestion along the major arterials and collector streets in the Lincoln Park community area (8, p. 112). This study was designed to measure the characteristics of this congestion in order to reduce conflicts between area residents, employees and visitors over available parking spaces.

In January 1978, the City of Chicago increased the cost of parking in city-owned parking garages (8, p. 148). Because many of these garages are located in the central business district, this increase should reduce downtown congestion.

Finally, efforts have also been made to constrain the total supply of parking spaces in the loop area. Within a special parking district in the central business district, designated through zoning, there has been no net increase in the number of parking spaces since 1973.

Pricing

1. Peak-Hour Tolls. This tactic consists of instituting private auto tolls during morning and evening peak periods on major bridges and expressways leading into the CBD.

2. High Occupancy Vehicle Toll-Reduction. This tactic consists of eliminating tolls for high occupancy vehicles and providing separate bypass lanes at toll gates for these vehicles.

3. Gasoline Tax. This tactic consists of establishing a regional program to increase local gasoline taxes.

4. Peak/Off-Peak Transit Fares. This tactic consists of having the regional transit authorities establish a program of reduced off-peak fares.

5. Elderly and Handicapped Fares. This tactic consists of establishing a regional fare structure that would benefit elderly and handicapped individuals.

6. Reduced Transit Fares. This tactic consists of establishing a flat-fare structure for the entire

metropolitan region. Ideally, the new fare would be lower than present fares.

RTA currently is studying the impact that various fare changes will have on transit ridership and modal choice. This study will yield price elasticities of demand for the various transit modes as well as estimates of the costs of fare collection for the different pricing schemes (8, p. 154).

RTA has established regionwide reduced fare programs for the elderly and handicapped on commuter railroads. The authority has also standardized child/student fares on commuter railroads (8, p. 159).

RTA will select two suburban bus companies to test the impact of reducing fares during off-peak periods (8, p. 166). RTA also plans to examine the effectiveness of innovative fare concepts in increasing transit usage.

# CHAPTER 4

## EFFECT OF TSM STRATEGIES ON TRAVEL AND VEHICLE EMISSIONS

This chapter contains a qualitative assessment of the motor vehicle reduction potential of individual TSM strategies. Each of the strategies discussed in the previous chapter is analyzed to determine its impact on vehicle emissions during peak and off-peak periods. Each strategy is also analyzed to determine its potential for reducing corridor carbon monoxide emissions and regional hydrocarbon and nitrogen oxide emissions. The applicability of these strategies in the Chicago region, if promising, will be evaluated in more detail.

In order to determine the emissions impacts of each TSM strategy, the transportation demand process was divided into its various elements of travel time, out-of-pocket travel costs, modal choice, trip length, and trip frequency. Based on a literature review of observed and model estimated travel impacts of TSM actions, judgements were made regarding the direction and magnitude of the travel demand impacts that would be induced by implementing a particular TSM strategy. The emission reduction potential of each strategy was then extrapolated from its travel demand impacts.

This procedure was necessary because the implementation of a specific TSM strategy generally alters several dimensions (elements) of urban travel demand and these

elements may partially offset one another with respect to emissions impacts. For example, the successful implementation of a carpooling strategy would result in a reduction in the number of vehicles traveling and hence reduce VMT during the peak period. But increased use may be made of vehicles that remain at residences during the workday and result in an overall increase of regional VMT.

The results of the qualitative assessment of the TSM emissions impacts are presented in Table 3. In the table a minus sign indicates a decrease in the factor, a plus sign indicates an increase. An N indicates a negligible impact, an M indicates a moderate impact, an S a substantial impact. The terms neglible, moderate, and substantial are used to denote relative rankings of only TSM related emissions and travel impacts. These terms have meaning only within the context of comparing one TSM strategy to another. The reader should note that the impact assessments developed in this project cannot be compared directly with the impacts of non-TSM strategies, such as inspection and maintenance programs.

Congestion-reducing strategies affect all vehicles but tend to be location or corridor specific. For example, traffic operations and signalization improvements are generally designed to facilitate vehicular movement through several intersections along major arterials. As a result, these strategies impact primarily on peak period travel time and system speeds and tend to reduce carbon monoxide

TABLE 3

QUALITATIVE IMPACTS OF TSM STRATEGIES ON TRAVEL DEMAND AND MOTOR VEHICLE EMISSIONS

| TRAVEL ELEMENTS | PERSONAL MOBILITY | | | | MODAL CHOICE | | | | | | | | TRIPS PER PERSON | | | | SYSTEM IMPACTS | | | | EMISSIONS | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Public Transit | | | | Private Auto/Van | | | | | | | | | | | | | | |
| TSM STRATEGY SETS | Travel Time | | Travel Cost | | Fixed Route | | Demand Responsive | | High Occupancy | | Low Occupancy | | Mean Length | | Mean Frequency | | Mean Speed | | Travel (VKT) | | Corridor (CO) | | Regional (NOx) (HC) |
| | P | OP | P | OP | P | OP | P | OP | P | OP | P | OP | P | OP | P | OP | P | OP | P | OP | P | OP | - - |
| Congestion Reducing Strategies | | | | | | | | | | | | | | | | | | | | | | | |
| 1. Traffic Operations | -M | N | N | N | N | N | N | N | N | N | N 1/ | N | N | N | N | N | N/+M 2/ | N | N 3/ | N | N/+M | N | N |
| 2. Traffic Signalization | -M | N | N | N | N | N | N | N | N | N | N 1/ | N | N | N | N | N | N/+M 2/ | N | N 3/ | N | N/+M | N | N |
| 3. Commercial Vehicles | -M | N | N | N | N | N | N | N | N | N | N 1/ | N | N | N | N | N | N/+M 2/ | N | N | N | -S | N | N |
| 4. Work Schedules | -M | N | N | N | N/-M | N | N | N | N/-M | N | N/+M | N | N | N | -S | +M/+S | N/+M 2/ | N | -M | +M/+S | N/-M | N/+M | -M/+M |
| Modal Choice Oriented Strategies | | | | | | | | | | | | | | | | | | | | | | | |
| 1. Pedestrians and Bicycles | N/-M | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N |
| 2. Roadway Assignment | | | | | | | | | | | | | | | | | | | | | | | |
| HOV/Bus | -S | N/-M | N | N | +M/+S | N | N | N | +M/+S | N | N/-M | N | N | N | N | N | +M/+S | N | N/-M | N | -M/-S | N | N |
| Auto | N/+M | N | N | N | | | | | | | | | N | N | N | N | N/-M | N | | | | | |
| 3. Route Diversion | N/+M | N/+M | N | N | N/+M | N/+M | N | N | N | N | N/-M | N | N/+M | N/+M | N | N | N | N | N | N | -M/-S | N/-M | N |
| 4. Transit Operations | -M | N/-M | N | N | N/+M | N/+M | N | N | N | N | N | N | N | N | N | N | N | N | N/-M | N | N | N | N |
| 5. Transit Management | N | N | N | N | N/+M | N/+M | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N |
| 6. Intermodal Coordination | -M | N | N/-M | N | N/+M | N | N | N | N | N | N | N | N/+M | N | N | N/+M | N | N | N | N | N | N | N |
| 7. Paratransit | +M/+S | N | -S | N | N/-M | N | N/+M | N/+M | +M | N | N/-M | N | +M/+S | N | N | +M/+S | N | N | -M | N/+M | N/-M | N | -M/+M |
| Congestion Reducing and Modal Choice Oriented Strategies | | | | | | | | | | | | | | | | | | | | | | | |
| 1. Parking Management | N | N | -M/+S | N/-M | N/+M | N | N | N | N/+M | N | N/-M | N | N | N | N | N | N 2/ | N | N 4/ | N | -M | N | N |
| 2. Pricing | N | N | +M/+S | N/+M | N/+M | N/+S | N | N | N/+M | N | -M/-S | N/-M | N | N/-M | N | -M/+M | N/+M | N | N/-M | N/-S | N/-M | N | N/-S |

1/ If congestion is a deterrent to auto travel, low occupancy auto mode may increase.
2/ Local speeds may increase.
3/ Local VKT may increase.
4/ Local VKT may decrease.

Key
N Negligible impact
M Moderate impact
S Substantial impact
\+ Increase
\- Decrease

P Peak period
OP Offpeak period
VKT Vehicle kilometers travelled

CO Carbon monoxide
$NO_x$ Nitrogen oxide
HC Hydrocarbon

emissions along major corridors and in the central business district (Table 3).

Modal choice oriented strategies are vehicle specific but may be area-wide in their travel demand impacts. For example, transit operation improvements are designed to increase mass transit throughout the region. Modal choice strategies impact primarily on peak-hour travel time and are designed to induce modal shifts by reducing transit travel time relative to that for a single occupant vehicle. Because these strategies are also generally designed for decreasing peak-period travel times, they also impact mainly on corridor and central business district carbon monoxide emissions (Table 3). Furthermore, the emissions-reduction potential for modal choice oriented strategies depends greatly on the extent of existing transit ridership levels. Modal choice strategies will have a smaller impact in metropolitan regions in which peak-period transit utilization rates are relatively high.

A few strategies are both congestion-reducing and modal choice oriented. These strategies, for example, peak-period tolls and parking charge increases, are not necessarily vehicle specific and may be implemented area wide. For the most part, these strategies also reduce peak-period carbon monoxide emissions.

Only three strategy sets, work schedule changes, carpool/vanpool programs, and gasoline price increases have the potential for affecting vehicle travel demand systemwide in both peak and off-peak periods, and as such, these strategies impact regional hydrocarbon and nitrogen oxide emissions, which are the precursors of photochemical oxidants.

## Traffic Operations

Traffic operations are designed to relieve congestion problems, especially in the short run. The tactics composing this strategy set are: intersection and roadway widening, one-way streets, turn lane installation, turning movement and lane use restrictions, and new freeway lanes utilizing existing shoulders.

Personal travel time reductions generally result from each of the tactics within this strategy set. Intersection and roadway widening, turn lane installation, and construction of a new freeway lane will all act to increase physical roadway capacity. One result of this increased capacity, all other things being equal, is a reduction in travel time. One-way streets, turning movement, and lane use restrictions serve to channelize traffic flows and in turn bring about travel time reductions. As an example, conversion in New York City to one-way streets allowed an observed 22 percent reduction in travel time and a 40

percent reduction in crosstown delays (23, p. 10.) Personal travel cost savings will result from decreased gasoline consumption for auto drivers due to lessened stop-and-go driving and reduced travel time.

Shifts in modal choice are not expected in any great quantity with any of the traffic operation tactics because all vehicles, including high occupancy vehicles, benefit from traffic operation changes. One negative aspect that may result from establishing one-way streets is that transit riders must walk further to board buses. This disadvantage may cause a slight shift away from buses to other modes. A shift towards auto modes may also occur if congestion problems are significantly relieved, especially if congestion is a major deterrent to auto use. However, such a shift would also be a marginal one.

Mean per person trip length will not increase with intersection and roadway widening, turn lane installation, and utilization of shoulders for a new freeway lane. One-way streets, turning movement, and lane use restricitions cause slight increases in mean trip length because the traveler may need to divert his path to accommodate traffic flows and restrictions. When this increase is averaged for all travelers the effect becomes rather small. None of the tactics impact on trip frequency.

Initially, average speeds will rise in the immediate area of any of these tactics, but volume increases may negate these speed increases. For example, it is estimated that average speeds increase ten to 40 percent through intersection and roadway widening (22, p. 2-12). In New York City after conversion to one-way streets a 65 percent drop in the number of vehicle stops occurred, accompanied by a 60 percent drop in time spent during stops (23, p. 10).

Total vehicle miles traveled for the entire transportation system will not be altered in the short run by traffic operation strategies. However, volumes in the immediate vicinity where the tactic has been implemented will increase. Widening intersections and roadways or installing turn lanes will generate larger volumes utilizing the facility. In the Chicago area five Traffic Operations Programs to Increase Capacity and Safety (TOPICS) improvements were completed for six intersections. Volumes increased at all intersections after the improvements were completed; increases varied from seven to 69 percent with an average increase of 39 percent (7). A new freeway lane will also cause volume increases along the improved facilities. One-way streets may not carry larger volumes, but a small rise in VMT may occur because of route diversions. For the system as a whole VMT changes very little.

Traffic operation strategies have been viewed as effective means of improving auto emissions for congested systems. Increases in speeds, combined with little change in systemwide VMT, indicate that a slight drop in hydrocarbon emissions will occur. However, in many instances conditions may worsen and emissions may not decrease at intersections which have been widened or channelized, because the volume increase overwhelms the speed factor.

One-way streets, new freeway lanes, and turn restrictions tend to increase speeds and promote steady flows with less stopping, idling, and accelerating. Emissions will improve for carbon monoxide and hydrocarbons, but not for nitrogen oxides. This is because carbon monoxide and hydrocarbon emissions decrease with increased speeds while nitrogen oxide emissions increase with increased speeds. Here also, local volume increases will mitigate or overwhelm carbon monoxide and hydrocarbon emission reductions. Regional oxidant levels will remain unaffected by traffic operation tactics.

## Traffic Signnalization

Traffic signalization tactics improve traffic flow through control by systematizing arterial and area signals, by developing freeway diversion and advisory systems, and developing freeway surveillance and control systems.

As with traffic operations, signalization strategies are directed toward reducing personal travel time. The greatest savings due to signal changes accrued from area or arterial signal systems and not from isolated intersection improvements. Increases in speeds for various cities resulting from signal improvement strategies are as follows: (3, p. A-8)

<u>Relative Increases In Travel Speeds</u>

| City | Percent Increase |
|---|---|
| Kansas City | 12 |
| Louisville | 01 - 24 |
| New York | 20 - 40 |
| San Jose | 10 - 12 |

Travel cost savings result from reduced gasoline consuption. Freeway surveillance and control, or ramp metering, is also an effective means for reducing the portion of total travel time spent on the expressway. The Los Angeles Harbor Freeway realized a considerable reduction in travel time (23, p. 7). Again, the traveler will save money through less gasoline consumed on the expressway, however, this travel time reduction is partly offset by longer waits to gain access to the freeway. Experience has shown that the advisory signing tactic is not as effective as the ramp metering tactic in generating time or cost savings.

Modal shifts are not impacted significantly by traffic signal changes; high occupancy vehicles, as well as autos, will gain from these tactics through better traffic flows. As with traffic operations, if congestion is a major deterrent to auto travel, a rise in single occupancy travel may occur.

Average per person trip length or frequency will not change with the implementation of traffic signalization alterations. Only if the traveler heeds freeway advisory signs, which indicate problems ahead and suggest alternative routes, and diverts his route, or, if he chooses not to enter a metered freeway, will trip length change.

A second large impact that signalization strategies produce is to increase average speeds. The expected range of speed increase is from ten to 40 percent (22, p. 2-12). Traffic delays may be reduced by as much as 60 to 70 percent (35, p. 62). Freeway ramp metering also generates increased expressway speeds. The Los Angeles Harbor Freeway average speed of 15 to 20 mph rose to 40 mph as a result of ramp metering; Dallas' ramp metering project generated average freeway speeds of 30 mph, an increase of 16 mph over pre-metering speeds (23, p. 7). Ramp metering may also cause congestion and lower speeds at ramps and arterial feeders. Systemwide speeds will not increase by the same magnitudes as in the improved intersections and arterials.

Local volumes may increase along arterials that have new signal systems, in areas with new systems, and through intersections with improved signals. This phenomenon is similar to that observed with traffic operation improvements. Freeway metering does not necessarily suffer from this local volume increase, as the tactic aims at controlling volumes on the freeway. However, a small rise in volume along parallel routes may occur because of route diversions. Total VMT will not change in any significant amount due to signal or freeway advisory or metering tactics.

Traffic signalization strategies have a limited potential for auto emission reductions. Increased speeds, less time delays, and a steadier flow of traffic will reduce carbon monoxide and hydrocarbon emissions. One must consider the increased local volumes for signal improvements as a mitigating factor, which could overwhelm any emission reduction potentials. Freeway metering, because of the possibility for controlling volumes, does offer emission reduction potential. Ramp metering projects prior to August of 1973 showed corridor carbon monoxide reductions of 18 pecent in Los Angeles (29, p. 8). Regional oxidant concentrations are unlikely to be impacted by signalization strategies because of their localized, small scale characteristics.

Commercial Vehicles

The strategy set commercial vehicles addresses the problems that trucks, taxis, and other commercial vehicles encounter. The tactics are: providing on-street loading zones, off-street loading areas, prohibiting peak-truck loadings, and developing a truck route system.

Commercial vehicle strategies do not decrease total vehicle miles traveled; they reduce congestion problems. As such, personal travel time will decrease, which in turn will generate some small travel cost savings. Commuters who pass through or end their trips in the CBD will realize the greatest time and cost savings because the problems these strategies address are worst in the CBD.

No significant changes in modal choice will result from these strategies. If congestion is eased in the CBD, some shift to low occupancy autos may occur, but the shift should be marginal. Trip length and frequencies will not change, though average speeds in the peak period in the CBD will increase due to relieved congestion.

Total vehicle miles traveled remains constant. A pilot project in London banned all daytime deliveries; total VMT did not change, although congestion was reduced (22, p. 1-65).

The effects of commercial vehicle strategies on auto emissions are negligible at the regional level; photochemical oxidant concentration levels will not drop,

although carbon monoxide concentrations in the CBD can be impacted by implementing these strategies. A vigorous program, including peak-hour bans on loading and off-street loading areas, could achieve substantial reductions in CBD carbon monoxide emissions.

## Work Schedules

The work schedule strategy set includes staggered work hour or flexitime actions and the four-day work week. These tactics address different problems and so will be considered separately.

Staggered work hours, also called flexitime, attempt to redistribute peak hour trips over a longer time period and thus reduce congestion. In New York City, where a staggered work hour program was instituted on the lower Manhattan subway lines, six percent fewer passengers were carried during the busiest 20-minute period of the peak. At the Port Authority Trans-Hudson terminal passenger volume dropped 87 percent during the busiest 15 minute period of the evening peak, while the lightest 15 minute period rose in volume 67 percent (23, p. 44). Personal travel time during the peak decreases because congestion decreases. Indirectly, personal travel costs also decrease.

Modal choice can be affected by staggering work hours. Fixed transit may not be responsive to changes in commuter time demands. Carpooling may become more difficult if

riders' work schedules are different. A shift towards the low occupancy auto mode will result if transit does not respond with re-scheduling and carpool matching programs (22, p. 2-97).

Mean trip length and trip frequency remain unaffected by staggering work hours.

In areas where work hour staggering occurs average speeds will increase. By spreading the peak hour volume over a larger time period an increase in average speed results. However, the total vehicle miles traveled will remain unchanged.

Implementing staggered work hours or flexitime will generate a decrease in carbon monoxide emissions. This will derive from shortened idling time, increased speeds, and a lessening of congestion. Further, a lessening of photochemical oxidant concentrations may be possible because of the spreading of peak hour volumes. It is estimated that if the morning peak in Los Angeles could be delayed one hour, photochemical oxidant concentrations could be lowered considerably (2, p. 2-30). The actual reduction in oxidant concentrations due to staggered work hours in general would not be nearly as great.

The four-day work week action focuses on diminishing vehicle miles traveled and could potentially produce a reduction of 20 percent in worktrip VMT. The optimal schedule is one where the labor's hours are rotated equally

over six days. This schedule will generate a 33 percent reduction in daily work trips for those firms who participate.

Assuming an equal six day rotation, personal travel time will decrease for each worker, due to less congestion near the place of employment. A small savings in costs may also occur through less gasoline consumption.

Modal choice remains basically unchanged by a four-day week. Carpools and vanpools may decline, due to different scheduling of car and van occupants. Most of these workers would shift to driving private autos.

The effects of a four-day work week on mean per person trip length and frequency are still unkonwn. Some feel trip length could increase; commuters might feel free to move further from work because the trip would be made only four days per week (21, p. 7-18). Work trip frequency drops as a result of a shortened work week. In contrast, shopping and recreational trips will grow in number due to more leisure time. The magnitude of the non-work trip increase is unknown, but could easily compensate for the decrease in work trips. Most sources state that vehicle miles traveled will not fall significantly. INTERPLAN states that the VMT reduction at best would be five percent (22, p. 2-103).

If non-work trips do not increase, carbon monoxide reductions during the peak-period will decrease because of fewer work trips will be made. However, since non-work

trips do increase, peak-period carbon monoxide emissions will drop by a lesser amount than above and off-peak carbon monoxide emissions will increase. Photochemical levels will worsen or improve depending on the amount of increase in non-work trips.

Staggering work hours will produce emission reductions only through easing congestion problems. Implementing a four-day work week will decrease emissions only to the extent VMT falls. However, by concentrating these actions in a certain specific geographic area and achieving a high participation rate, these actions can be effective in reducing local carbon monoxide emissions.

## Pedestrian and Bicycle

TSM actions which compose the pedestrian and bicycle strategy set include widening sidewalks, constructing bikeways, bike storage, and pedestrian control barriers.

1970 census data reveals that seven percent of all urban work trips are walking trips, which are twice the number of rapid rail trips (46), and that the proportion of walking trips is declining. Promotion of human power modes of travel alone yield small reductions in emissions compared to other strategy sets. A vigorous program to improve pedestrian and bicycle modes can achieve a reduction in personal travel time for the bicyclist or walker, although the reduction would be a small one. For those travellers

who switch to walking or cycling from auto modes, reduced gasoline consumption will produce cost savings.

Provision of pedestrian amenities would not achieve a significant shift in modal choice away from the auto. Mass transit easily compliments both walking and bicycle modes, so a small rise in transit ridership might result from this strategy set. In California, bus routes exist that serve the cyclist by providing room for bikes to be transported, such as in a trailer. These services are popular, successful, and are being expanded (23, p. 90).

Changes in trip length will not be affected by these actions in any substantial magnitude. One must note, though, that human power can only be used for short trips and is inapplicable to long trips. Similarly, trip frequency will not change. Systemwide speeds and total vehicle miles traveled remain constant, and thus, significant emission reductions are not expected.

Pedestrian and bicycle modes are not actions in and of themselves to promote significant emission reductions; however, they may serve as minor auxiliary programs to transit and paratransit strategies, and as required elements of programs to restrict auto access and to attract transit ridership (22, p. 1-67).

Roadway Assignment

Roadway assignment strategies are six in number: exclusive bus lanes on arterials, bus-only streets, contra-flow arterial bus lanes, reversible lane systems, freeway high occupancy vehicle bypasses, and exclusive bus and high occupancy vehicle freeway lanes. Each will be discussed separately.

Exclusive bus lanes on arterial streets have been implemented throughout the United States, yet very little data exists on their impacts. Arterial bus lanes have produced varied time savings. In Baltimore, Maryland, the observed savings is between 17 and 21 percent, in Dallas, Texas five to 20 percent; in New York City 22 to 42 percent (23, p. 34). In Arlington, Virginia, travel time decreased ten to 20 percent (32, p. II.7). Travel costs are not impacted because the auto driver realizes no cost benefit from bus lane implementation. This tactic attempts to induce a shift away from auto modes to buses. Only in New York did bus ridership not increase (23, p. 34). Exclusive bus lanes do not affect trip length or frequency. No data was found on speed; however, bus speeds will increase due to the absence of other traffic in bus lanes. Systemwide speeds will not be significantly altered. VMT changes will be marginal in nature, and hence, emission impacts will be negligible.

Bus-only streets exist in Minneapolis, Minnesota; Washington, D.C.; and Philadelphia, Pennsylvania (23, p. 36). No data was found regarding bus only street impacts. Bus service becomes more accessible when auto traffic must divert to parallel streets and congestion may rise. Auto emissions, including hydrocarbons, carbon monoxide, and nitrogen oxides, decrease along the bus-only street if, prior to conversion, the street was moderately to heavily traveled. This reduction may be countered by increased auto emissions on adjacent streets. Regional oxidant levels will not change.

Contra-flow arterial bus lanes usually are created on light-flow direction streets in order that buses may save time in peak-periods and not utilize a heavy-flow direction lane on the coupled street. In Louisville, Kentucky, time savings have amounted to 25 percent for bus riders between the central business district and park-and-ride lots (23, p. 35). These savings will induce transit ridership increases and a small decrease in heavy-flow directional auto traffic. Trip length may possibly increase for transit riders due to the route diversion to a contra-flow lane and some transit riders may have to walk further to load on the bus or arrive at their destination. Peak bus speeds increase with no other traffic in their lane and auto speeds may also increase because of the absence of buses on the heavy-flow direction street. Arterial VMT will fall if a modal shift

to transit occurs and a related local reduction in emissions will take place.

Reversible lane systems offer no preference to buses or high occupancy vehicles. These systems focus on increasing capacity in the heavy-flow direction. Increased capacity allows traffic to flow at a higher speed, which translates to time and cost savings for the traveler. If congestion serves as a deterrent to auto travel, a shift towards auto modes will occur when congestion is temporarily relieved. In this case volumes will increase, congestion will return, and local emissions will rise.

Freeway high occupancy vehicle bypasses provide a special lane which allows high occupancy vehicles to circumvent bottleneck problems. Seattle, Washington; Minneapolis, Minnesota; and Los Angeles, California have instituted freeway ramp bypasses. In Seattle a reversible CBD bus ramp yeilded an 11 to 23 percent total time decrease for bus passengers (23, p. 25). Los Angeles constructed 13 high occupancy vehicle ramps and a one to three minute time savings was observed for high occupancy vehicle travelers (24, p. B-18).

Tunnel and bridge bypass lanes exist in New York City and on the San Francisco-Oakland Bay Bridge (SFOB). The Lincoln Tunnel bus lane approach and associated reversible lane has generated a bus total travel time reduction of 44 percent (24, p. 27). High occupancy vehicle travelers on

the SFOB Bridge have realized a five to eight minute reduction in travel time (23A, p. B-27). In those instances where an additional lane is provided for high occupancy vehicles autos may also realize time savings.

Modal choice is shifted towards transit and shared ride modes with bypass implementation. Bus ridership and the number of carpools increase when high occupancy vehicle bypasses are implemented. In Minneapolis transit ridership grew 13 percent while auto drivership decreased (24, p. B-25). Los Angeles observed a 13 percent increase in bus ridership and a doubling and in some cases trebling of carpools utilizing the high occupancy vehicle ramps (24, p. B-25). In Seattle bus ridership rose while auto driver numbers fell 22 percent (23, p. 25). Bus ridership through the Lincoln Tunnel rose six percent (24, p. B-27). Carpools on the SFOB Bridge approximately doubled (23, p. 26). The existence of commuter/rail along the corridor will dampen the shift towards high occupancy vehicle modes. Cities with high transit ridership also may not realize such large shifts in modes.

Trip length and frequency are not significantly affected by bypass tactics. Only if a driver chooses to carpool, or must travel further to board a bus, will trip length increase. Speeds in the p.m. peak increased 32 percent in Minneapolis and up to tenfold on the Lincoln Tunnel approaches (24, pp. B-25, B-27).

In general, VMT drops as bypasses are installed. However, volumes rose on the Lincoln Tunnel approaches.

The final assignment tactic, freeway high occupancy vehicle and bus lanes, has the most data available and promises potential as an effective means of reducing emissions. Percent time savings associated with freeway HOV and bus lanes are shown in Table 4.

TABLE 4

TOTAL TRIP TIME SAVINGS ATTRIBUTED TO EXCLUSIVE FREEWAY HIGH OCCUPANCY VEHICLE AND BUS LANE TIME SAVINGS

| Location | % Time Saved Over Auto | Actual Time Saved Over Auto |
|---|---|---|
| Long Island Expressway | | |
| Southeast Expressway (Boston) | 22-75 | |
| San Bernadino Expressway | 42 | |
| Santa Monica Expressway | 50 | |
| Banfield Expressway (Portland) | | 4 minutes |
| Shirley Highway | | 15 minutes |

The reductions are substantial and act as a powerful incentive in drawing transit and shared ride travelers. Bus

ridership rose in all cases, from three percent on the Southeast Boston Expressway (38, p. 38), to 350 percent on the Santa Monica Expressway (24, p. B-17). The Banfield Expressway and the San Bernadino Expressway both achieved ridership increases of over 250 percent (24). Carpool numbers also rose where preferential treatment was given. The Southeast Boston Expressway experienced a greater than 100 percent increase in carpool numbers (38, p. 31), as did the Santa Monica and Banfield Expressways. Clearly, modal choice can be influenced in a substantial way with exclusive lanes.

As with the bypass tactic, trip frequency is not impacted greatly by exclusive lanes. Trip length will increase if the commuter must travel further to gain access to buses using the exclusive lanes, or if he chooses to divert his route and pick up car passengers.

Bus speeds definitely increase with the use of exclusive lanes; carpool speeds also increase when carpool use of exclusive lanes is allowed. For instance, buses experienced at least a 45 percent increase in speed on the Long Island and Southeastern Boston Expressways (32, p. II.3). On the San Bernadino Expressway bus speeds incrased 55 percent while nonpreferential traffic speeds rose more than 35 percent (32, p. II.3).

VMT impacts vary from project to project. On the I-95 freeway in Miami volumes rose 20 percent (38, p. 28). The Southeast Boston Expressway experienced a VMT decline of ten percent, the Santa Monica Expressway a decline of nine percent (38, p. 18). It appears that in most cases VMT will fall due to increased auto occupancy rates and increased transit ridership.

The Shirley Highway project in Virginia generated a 21 percent reduction in auto emissions (32, P. II.7). This exemplifies the potential that exists for auto emission reduction through freeway preferential lane implementation. Increased speeds and decreased volumes both serve to lower carbon monoxide and hydrocarbon emissions during peak periods. Freeway lanes impact corridor emissions and are not nearly as effective in impacting regional oxidant emissions. This is because regional volumes are not greatly altered by freeway high occupancy vehicle and bus lanes.

## Route Diversion

Residential traffic control, area licensing, pedestrian malls, and auto restricted zones are the actions that constitute the strategy set of route diversions. These actions attempt to limit vehicle use through managing auto access.

All route diversions tend to reduce personal mobility for the low occupancy auto mode. Travel times increase for the traveler, as well as travel costs. For example, a pedestrian zone in London, England, the Oxford Street Mall, caused travel times to increase 15 percent for vehicles passing through this zone (41, p. 308). In Berkeley, California, where residential traffic controls were implemented, residents complained of excessive time delays, especially to emergency vehicles (23, p. 101) and twice attempted to remove the controls. Associated travel costs also increase.

Modal choices are induced to shift towards non-auto modes through route diversions. Area licensing, pedestrian malls, and auto restricted zones all serve to pressure travelers out of the auto if their destination lies within a restricted area. Some may shift modes towards the end of their trip, others may shift for the entire trip. Further, travelers who must pass through the affected zone may choose to switch to transit, for example, to avoid diversions and congestion problems. Allowing transit access and movement through these restricted areas will add to the attractiveness of the transit modes over the auto. Hence, a moderate shift may be induced, away from the auto and towards mass transit. For example, in Singapore, Malaysia, an area licensing program was established for the CBD, where auto users (excepting carpools) had to obtain a license to

drive and park in the CBD. Because buses were exempt, bus travel times decreased and morning peak traffic fell 40 percent; bus ridership grew substantially (23, p. 52-53).

Trips will lengthen for those persons who must divert their path around a restricted area, or a residential traffic blockade. Those persons who end their trip in a restricted area, whether licensed or prohibited, will encounter little or no increase in trip length.

On streets in the immediate area, especially parallel streets, volumes will increase and consequently, speeds will decrease. In London, on streets parallel to the Oxford Street Mall, volumes rose from 200 to 800 vehicles per hour and speeds fell to 6.5 mph from eight mph. However, the flow patterns tended to level out from 9:30 a.m. to 5:30 p.m. and reached a plateau value with less acute rush hour peaks (41, p. 308). Obviously, within the restricted zone volumes will drop considerably.

Emissions, on a local scale, can be substantially reduced by implementing area licensing, pedestrian malls, or auto restricted zones. For example, air pollution levels in Tokyo were cut in half when cars were banned from 122 streets on Sundays. When Madison, Wisconsin, was closed to traffic, carbon monoxide concentration levels dropped from 22 ppm to eight ppm (2, p. 37). But care must be taken to consider possible emission increases due to increased travel times, decreased speeds, and increased volumes on

neighboring streets. Regional emissions of nitrogen oxides will not likely change, since route diversion programs are local in nature.

## Transit Operations

Transit operation strategies attempt to induce a modal shift towards mass transit by making transit more attractive.

The most effective service improvements in attracting new riders are those improvements which lower personal travel time. Bus route and schedule modification is one means of reducing travel time; instituting or improving express bus service is another. These tactics improve service while leaving auto travel time unchanged. Bus traffic signal pre-emption also lowers transit travel time; however, auto travel time increases. In Los Angeles, for example, transit travel time dropped five to seven percent with bus pre-emption, while auto travel time was observed to increase (23, p. 39). At Kent State University, bus traffic signal pre-emption lowered transit travel time ten percent (23, p. 39). In Washington, D.C., bus prioritization reduced delays 35 percent (24, p. B-44). Outfitting express buses with traffic signal pre-emption devices allows a greater time savings by allowing buses quicker access to the CBD on the nonexpressway portions of their routes. In Louisville, Kentucky, nine express buses

were outfitted to pre-empt eight traffic signals. Time savings were 9 to 19 percent over unequipped local buses (23, p. 39). Simplifying fare collection and providing bus terminals do not impact greatly on travel time.

None of the strategies impact on personal travel costs directly. A passenger pays a fare which is unaffected by the time savings he may realize.

As stated earlier, transit operations attempt to create modal shifts towards fixed route transit. INTERPLAN states that during the first six weeks of 1974, in individual cities with service improvements, ridership showed increases of ten to 20 percent (22, p. 1-18). For the Washington, D.C. region it is estimated that increasing express bus frequencies by scheduling buses will increase commuter transit ridership one percent (36, p. 46). Atlanta, Georgia, between 1972 and 1975, saw a 25 percent annual increase in ridership due to increased service, route changes, and fare reductions (24, p. B-1).

Mean per person trip length and frequency will not be altered substantially by transit operations strategies. Some travelers may take a slightly longer transit trip and some additional trips may be made if the use of an auto becomes available at home. These effects will be small when related to the region as a whole.

Systemwide average speed will not noticeably rise or fall, even though bus speeds may increase through traffic signal pre-emption.

Vehicle miles traveled also will not be altered greatly, although some reduction in VMT should be generated. Peak VMT may decline moderately, but the extent of the decline depends on the degree of saturation of mass transit services. Off-peak VMT is not in general impacted by transit operation strategies because the demand for transit is not overly responsive to operation changes. For Baltimore, reducing the average transit waiting time by one minute was estimate to yield a very optimistic two percent drop in regional VMT (22, p. 1-25).

Auto emission reductions are expected to be relatively small. Route and schedule modifications, according to one source, will produce less than a five percent drop in emissions (17, p. 11).

## Transit Management

Transit management strategies include marketing programs, maintenance improvements, vehicle fleet improvements, and operations monitoring programs. The last three, while widely implemented, have little data describing their effects on ridership and emissions. In contrast, marketing programs combined with service improvements, such as reduced headways and increased routes, have yielded a

wealth of information.

Maintenance fleet and monitoring programs strive to make transit more efficient and modern. This will create some small travel time savings through greater realiability. However, the transit rider will realize no cost savings, as his fare is not directly and immediately responsive to better management.

Specific marketing programs have yielded modal shift information. An example of a ridership increase attributed to marketing programs can be found in Duluth, Minnesota, where installation of a telephone information center generated a 26.6 percent increase in ridership (23, p. 1089). In Cleveland, Ohio, a market analysis and advertising campaign resulted in ridership revenue increases that were 250 percent larger than the required increase in the advertising budget (23, p. 108).

Mangement strategies do not impact on trip length, or average speed. Trip frequency may rise in off-peak hours due to the increased availability of an auto at home. If a modal shift does occur, a small reduction in VMT may be expected. However, regional auto emissions will not be reduced in any significant amount. Carbon monoxide emission reductions may be realized during the peak, but again, the magnitude of the reduction will be small.

Intermodal Coordination

Intermodal coordination includes two tactics, instituting park-and-ride facilities, and improving transfers.

Personal travel time will decrease with improved transfers. Commuters who use park-and-ride facilities may or may not shorten their work trip. If the transit facility used is express and the total trip length comparable to the auto trip, they will save time. If, however, the transit facility used is express and the trip length is greater than the auto trip length, or they have to walk a long distance, travel time will increase. Travel costs will decrease for park-and-ride travelers. In Toledo, Ohio, it is estimated that commuters can save $1000 per year due to free parking and a 35 cent fare (23, p. 68).

Intermodal coordination strategies attempt to increase transit ridership. Park-and-ride facilities have displayed varying degrees of success. In Atlanta, two lots where data have been collected are utilized at 100 percent of capacity and 40 percent of capacity (24, P. B-2). Boston has 18,000 parking spaces along transit lines, which are estimated to be between 80 to 100 percent used; Portland reports a rate of 28 percent (24, p. B-13, B-33). In all these cases ridership on the associated transit facility has increased. However, where park-and-ride facilities already exist these strategies will generate only marginal ridership increases.

Trip length will not change for transfer improvements, nor will trip frequency. Park-and-ride facilities may require travelers to take a longer trip, but if the route is lengthened considerably the traveler will not use the park-and-ride mode. Trip frequency will also rise in many cases. Many commuters are dropped off at the lots so that the auto is available for use during off-peak hours.

If park-and-ride facilities are provided and highly utilized along an urban corridor, average speeds will increase due to lower vehicle volume during peak hours. Further, if facilities are provided along main transit lines, systemwide vehicle miles traveled will fall during the peak. Park-and-ride facilites can produce reductions, during peak hours, in carbon monoxide emissions if none were in existence prior to implementation of these strategies. These reductions may be offset in part by off-peak increases in emissions due to increased VMT, although these increases will be small. Regional photochemical levels will not be impacted greatly, because of the moderate reductions in overall VMT.

### Paratransit

Paratransit strategies include carpool matching programs, vanpool programs, taxi/group riding programs, dial-a-ride programs, jitney services, and elderly and handicapped services. The first two tactics command the

most attention in the literature and have thus accumulated the greatest amount of data.

Travel time increases for carpoolers and vanpoolers, because the shared vehicle must divert to pick up other riders before proceeding to the destination; on return trips each passenger must be let off. 3M employees in St. Paul, Minnesota, experienced a 30 percent average increase in travel time (23, p. 77). The remaining tactics do not focus on or change personal travel time.

Carpool and vanpool programs act to lower travel cost and utilize this saving as the major incentive to convert travelers to shared ride modes. Savings are greatest with higher passenger numbers and longer trips.

Paratransit strategies attempt to induce shifts in modal choice towards shared ride and demand responsive transit modes. Carpool matching efforts in 29 U.S. cities generated an average new carpool ridership of 16 percent of those who requested matching assistance. This constitutes slightly less than one percent of the areawide employment (25, pp. 63, 65). An areawide model carpool program for the Washington D.C. area generated a shared ride increase of four percent, a transit ridership decrease of one percent, and a single-occupancy auto decrease of two percent (32, p. II.13). Vanpool programs at individual major employers have generated negligible ridership increases; 42 to 49 percent of new vanpoolers drove alone before pooling,

50 to 58 percent carpooled, and one or more percent used to be transit riders (32, p. II.13). Dial-a-ride, jitney, and elderly and handicapped programs also attempt to attract riders from other modes. However, modal shift data could not be found for these modes.

Per person trip length increases in the same manner as trip time for carpool and vanpool programs. Carpools and vanpools are more successful when the distances between passenger residences are shorter and the linehaul distance is longer, because the increased distance and time required to pick up passengers is small relative to the entire trip length.

Paratransit strategies tend to enhance mobility for the mobility restricted. For this reason trip frequency often increases when paratransit facilities are provided. Dial-a-ride and jitney service trips may result from new demand created by these services (22, p. 1-47). Most of these new trips will be off-peak trips. Carpool and vanpool programs can also induce new trips through the availability of an auto that the car or van passenger leaves at home.

System speeds are not apt to be substantially altered. If carpool and vanpool programs are carried out area-wide and succeed in raising average vehicle occupancy by more than a marginal amount, congestion may then be relieved and peak speeds may increase. However, extensive jitney, dial-a-ride, and elderly and handicapped services add

off-peak volume to the system and may reduce speeds by a small amount. The expected impact of these tactics on system speeds is negligible.

Carpool and vanpool programs reduce vehicle miles traveled by increasing auto occupancy. The Washington D.C. carpool model program mentioned earlier predicts a less than one percent drop in total VMT with a one to two percent drop in work VMT (32, p. II.13). Carpool programs in Portland, Oregon generated an estimated one percent decrease in work VMT. In Boise, Idaho, the decrease was estimated at one percent; in Tucson, Arizona, the estimate was four percent (25, p. 76). Vanpool programs have also affected VMT. In St. Paul, Minnesota, while daily city-wide VMT grew 35 percent during the first three years of the vanpool program, local VMT near the 3M center grew only 17 percent (24, p. B-25). However, dial-a-ride, elderly and handicapped services, and jitney programs tend to raise off-peak VMT, albeit the increase is small.

Paratransit strategies provide a mix of impacts on auto emissions. Peak emissions, both carbon monoxide and hydrocarbons, are reduced through carpool/vanpool programs. The major source of this reduction is the decreased peak VMT. In contrast, paratransit tactics act to increase off-peak hydrocarbon and carbon monoxide emissions. Negligible to moderate reductions in regional photochemical oxidant levels were also noted, which supports the theory

that regional photochemical oxidant levels are due to cold starts. If, however, these levels are due to midmorning to evening hydrocarbon emissions, then moderate increases may be possible.

Parking Management

Parking management strategies include curb parking restrictions, residential parking controls, off-street parking restrictions, preferential rates for high occupancy vehicles and short term parkers, and preferential spaces for high occupancy vehicles.

Curb parking restrictions generate personal time savings, while the other parking tactics do not impact travel time directly. Restricting curb parking allows road capacity to be increased substantially. This results in time savings of 25 percent for autos and 20 percent for local buses during peak periods (23, p. 13). The remaining control strategies will affect travel time by forcing the auto driver to walk further, or by allowing the carpooler to park closer to his destination.

Travel costs are also impacted by parking tactics. One means of controlling off-street parking is through raising parking fees, which increases travel costs. Preferential rates for high occupancy vehicles and short-term parkers will lower their travel costs.

Parking management strategies pressure auto travelers to shift their mode choice. Curb parking restrictions act as a disincentive for auto drivers and hence a shift to other modes, such as bus and carpools, will occur. For Washington D.C. it is estimated that elimination of all on-street parking in the core would cause auto (driver only) numbers to drop one percent, while the transit mode would increase one percent and auto occupancy would rise one percent (35, p. 49).

A good example of off-street parking restrictions occurred in Pittsburgh, where in 1972 a three day strike closed down most off-street parking lots. Transit ridership increased 12 percent during the three days while CBD bound auto trips decreased 25 percent. After the strike, the mode choices returned to pre-strike levels (28, p. 40). Another estimate states that if ten percent of all privately owned spaces in private lots and garages in the Washington D.C. core were eliminated, transit ridership would increase six percent, auto occupancy would increase seven percent, and auto driver trips would decrease eight percent for work trips (36, p. 50).

Preferential rates for high occupancy vehicles induce shifts towards higher occupancy rates. If a reduction in parking fees for carpool vehicles in lots and garages were implemented in Washington, D.C., transit ridership would decrease by an estimated one percent while auto occupancy

would increase an estimated one percent (36, p. 47). In Los Angeles a parking tax increase of $0.25 is estimated to cause a drop in auto trips of eight percent; a $1.00 increase is estimated to cause a 21 percent drop (23, p. 63). In Baltimore, Maryland, preferential high occupancy vehicle parking spaces are 93 percent utilized (24, B-4). In Washington D.C. reservation of convenient spaces for carpool vehicles is estimated to reduce auto driver numbers one percent and increase auto occupancy one percent (36, p. 46).

Mean per person trip length and frequency will not change significantly with parking strategy implementation. Curb and off-street restrictions may force the driver to park further from his destination and walk further, while preferential high occupancy vehicle parking treatment will mean high occupancy vehicles may be able to park closer to work places. However, total length will not vary substantially.

Average speeds in core areas will increase with parking management programs. Curb restrictions can generate speed increases of five mph or more with a possible 50 percent reduction in traffic delays and stops (23, p. 13). Off-street parking restrictions will generate speed increases through volume decreases in the core area.

Volume decreases can also be obtained through parking strategy implementation. For example, one estimate states that a two percent drop in central business district VMT can be attributed to a 25 percent tax on parking in San Francisco (23, p. 63). In Los Angeles a parking tax increase of $1.00 is estimated to reduce total daily VMT by 15 percent. Rate increases of $0.75 to $1.00 per day in different cities are projected to reduce CBD VMT by three to seven percent (23, p. 64). When these CBD reductions are averaged into total VMT reduction the effects become less noticeable.

Parking strategies offer potential as an effective means for dealing with CBD emission problems. Local speeds are increased and volumes are reduced, both of which serve to reduce carbon monoxide and hydrocarbon emissions. For the region as a whole, photochemical oxidant levels are not likely to be substantially reduced.

## Pricing

Pricing strategies are varied and affect the transportation system in different ways. The strategies include: peak hour tolls, low occupancy vehicle tolls, a gasoline tax, peak/off-peak transit fares, elderly and handicapped fares, and reducing transit fares.

Peak hour tolls and low occupancy vehicle tolls both serve to relieve congestion, and thus to decrease travel time. Perhaps the most effective low occupancy vehicle toll is to allow high occupancy vehicles to pass toll plazas without stopping; that is, high occupancy vehicles do not pay a toll while autos do. Such a system was implemented on the San Francisco-Oakland Bay Bridge. As a result high occupancy vehicles take five to ten minutes less time to cross the bridge (23, p. 41). Peak hour tolls attempt to discourage peak-hour use of highway facilities. If volumes are reduced travelers benefit from a time savings.

Pricing strategies impact most directly on travel costs. Peak hour tolls, low occupancy vehicle tolls, and gasoline taxes act to make travel more costly and induce travelers to travel less, at nonpeak hours, or in high occupancy vehicles. Off-peak transit fares, elderly and handicapped fares, and reduced transit fares serve to reduce travel costs.

Pricing policies also affect modal choice differently. Peak-hour tolls do not focus on mode choice and so do not induce modal shifts. Low occupancy vehicle tolls provide a disincentive for auto drivers. This disincentive results in a shift away from low occupancy autos to transit and carpool/vanpool modes. For example, the San Francisco-Oakland Bay Bridge project mentioned above resulted in carpool increases of five percent (23, p. 41).

Gasoline taxes also induce shifts away from low occupancy autos. The October 1973 oil embargo provides insight into the effects of higher gas prices on travel. In San Francisco, bus ridership rose late in 1973 by 20 percent. In Los Angeles by June of 1974 carpools increased ten percent (22, p. 3-43).

Peak/off-peak transit fares serve to induce transit ridership, especially during off-peak hours. In Allentown, Pennsylvania a $0.10 decrease in off-peak fares generated a Saturday ridership increase of 110 percent, while off-peak weekday ridership rose 73 percent; in Trenton, New Jersey a $0.15 differential between peak and off-peak fares induced a 50 percent off-peak ridership increase (23, p. 110).

Reducing transit fares generates across the board increases in transit ridership. Portland, Oregon and Dayton, Ohio have instituted no-fare zones in their downtown areas. In Dayton riderhip in the no-fare zone increased several hundred percent, while citywide transit ridership increased 14 percent. Auto use dropped 28 percent. In general, fare reductions, off-peak transit fares, and special fare programs have been found to induce transit increases of between ten and 25 percent (23, p. 108).

When travel costs become considerably higher through pricing strategies travelers will shorten their trips. Home-work trips may, over the long run, become shorter as people choose to live closer to work or vice versa. In the

short run, if costs are high enough, non-work trips will be shortened; for instance, people will shop closer to home.

Trip frequency is also impacted by pricing policies. A high gas tax will force curtailment of non-work trips. Off-peak fares and elderly and handicapped fares tend to induce new trips that otherwise would not be made.

Average speeds can be increased by implementing peak-hour tolls and low occupancy vehicle tolls. If congestion is relieved speeds will increase. Gasoline taxes reduce volume, which allows speed increases to occur.

Volume decreases with pricing strategy implementation. Low occupancy vehicle tolls, gasoline taxes, peak-hour tolls, and reduced transit fares all serve to decrease vehicle miles traveled. The induced off-peak transit trips due to off-peak fares and elderly and handicapped fares may not be as large as the total VMT reductions from other combined pricing policies, but may induce a VMT increase which would reduce the total benefits of such schemes.

Peak-hour tolls and low occupancy vehicle tolls offer potential for reducing carbon monoxide and hydrocarbon emissions along highway corridors. Gasoline taxes and reduced transit fares impact emissions at the regional scale. However, substantial emission reductions can be generated only by tax and fare policies that are not marginal in nature. Off-peak transit fares and fares for the elderly and handicapped serve goals that are not air quality oriented and do not decrease auto emissions.

# CHAPTER 5

# TECHNICAL AND PUBLIC ACCEPTABILITY OF IMPLEMENTING TSM STRATEGIES

## Introduction

Discussed in this section are some of the technical and public acceptability considerations which are likely to facilitate or impede the implementation of varius TSM measures aimed at reducing mobile source emissions. This discussion deals with these factors in a general way and no attempt has been made to assess any of the specific TSM feasibility questions that might arise in the Chicago region. Before examining questions of feasibility for the thirteen specific TSM strategies, however, some comments regarding the general nature of TSM programs are needed.

First, any statement regarding the feasibility of implementing a coordinated set of TSM measures for improving air quality must necessarily be speculative at this time. The TSM program as promulgated in joint regulations by the Urban Mass Transportation Administration (UMTA) and the Federal Highway Administration (FHWA) (Federal Register, 1975) is still relatively new. There has not been a great deal of experience in implementing many of the potential TSM tactics, and the full extent of the feasibility of some of the individual tactics or combinations of tactics cannot be assessed at this time.

Second, because of the newness of the TSM program and because of difficulties in interpreting the Federal regulations, the TSM planning philosophy of using a full complement of "short-range" and "low-cost" transportation management options to improve system operations and efficiency is just beginning to permeate metropolitan planning organization procedures. Although these procedures have for many years included some TSM tactics, notably traffic operations improvements tactics, the notion of coordinating a large number of these tactics into an integrated plan for systemwide improvements is just beginning to emerge. Gakenheimer and Meyer (1977) discuss a number of issues which need to be restated here that relate to metropolitan planning organization response and performance under the TSM program. Because most individual TSM tactics have very slight impacts on mobile-source emissions, coordinating a large number of tactics into an integrated plan is the essence of the challenge of using TSM to improve air quality.

Implementation Feasibility of TSM Strategies

The feasibility of implementing various TSM strategy sets can be ascertained quickly through their effects on travel by single occupant autos. Impact on the mobility of personal vehicles is in all likelihood the single most important criterion in determining implementation

feasibility. Those strategies which tend to improve travel conditions for single occupant autos or provide options for such drivers (e.g. carpool/vanpool programs, express buses, or traffic operations improvements) are likely to be more feasible from both the political and technical standpoints. Those strategies which restrict the ease or opportunities of using single occupant autos (e.g. pricing, parking restrictions, roadway assignment, or auto restricted zones) are likely to be less feasible, especially from a political or public acceptance standpoint.

Impact on the cost of travel by single occupant vehicles is another important criterion for determining implementation feasibility, but cost impacts are generally not as important as mobility impacts. Actual out-of-pocket driving expenses are perceived to be only a very small part of the total cost of traveling by car. The significant element of this criterion, however, is not "how much" but whether or not the individual traveller pays directly the additional expense. Those strategies which result in individuals directly paying the increased expenditures are likely to be less feasible than those strategies which are paid through public expenditures.

Some additinal criteria for judging the implementation feasibility of TSM strategies include: 1) the ease with which required enforcement procedures can be instituted, e.g., the ease with which single-occupant vehicles can be

excluded from exclusive bus lanes, 2) the length of time that it takes a TSM strategy to be adopted, e.g., the time that it would take for a shift to staggered work hours to become effective, and, 3) legal and institutional problems, e.g., the need for new legislation or institutional arrangements to facilitate TSM implementation.

The implementation feasibility of the thirteen TSM strategy sets was determined using these five criteria. A summary of the findings is presented in Table 5.

TABLE 5

IMPLEMENTATION FEASIBILITY OF TSM STRATEGY SETS

| TSM STRATEGY SET | AUTO MOBILITY IMPACTS | CAPITAL AND OPERATING COST IMPACTS | ADMINISTRATIVE AND TECHNICAL ENFORCEABILITY | PUBLIC ACCEPTABILITY | INSTITUTIONAL REQUIREMENTS |
|---|---|---|---|---|---|
| Congestion Reducing Strategies | | | | | |
| Traffic Operations | Improves auto mobility. | Public sector bears costs. Program costs are low relative to new construction. | Little administrative and technical enforcement required. | Public acceptance already exists. | Problem exists with getting funds due to backlog of previously committed projects. |
| Traffic Signalization | Improves auto mobility. | Public sector bears costs. Program costs are low except for ramp metering and advisory signing. | Little administrative and technical enforcement required. | Public acceptance already exists. | Problem exists with netting funds due to backlog of previously committed projects. |
| Commercial Vehicles | Improves auto mobility. | Private sector bears some of the costs. Public pays for truck route development. | Private interests must administer new delivery hours, places, and routes. | Resistance is likely from unions, stores. | Legal changes to require off-street loading may be required. |
| Work Schedules | Improves auto mobility indirectly. | Private sector bears most of the costs. | Administrative difficulties exist for certain firms. | Management and unions may resist implementation. Potential for public acceptance exists. | |
| Modal Choice Oriented Strategies | | | | | |
| Pedestrians and Bicycles | Increases non-auto option. | Public sector bears costs. Costs can be low. | Little technical adjustment is needed. | Barriers exist to people who can or will not use facilities. No strong tendency for public acceptance exists. | |
| Roadway Assignment | Detrimental to auto mobility. Increases non-auto options. | Public sector bears costs. | Enforcement and safety problems can occur. | If project is well-planned and integrated, potential for public acceptance is high. | |
| Route Diversion | Restricts auto mobility and general access. | Public and private sectors share cost burden. Malls require large capital costs. | Enforcement may be difficult. | Interest groups may resist program. Potential for public acceptance exists if well planned. | |
| Transit Operations | Increases non-auto options. | Public sector bears portion of costs through subsidies. | Transit authority must administer program. Technical requirements are not major. | Program may be successful in attracting riders. Program has some public acceptance potential. | Funding can be difficult. Application process is time consuming. |
| Transit Management | Increases non-auto options. | Public sector bears portion of costs through subsidies. | Transit authority must administer program. Technical requirements are not major. | Program may be successful in attracting riders. Program has some public acceptance potential. | Funding can be difficult. Application process is time consuming. |
| Intermodal Coordination | Increases non-auto options. | Public sector bears portion of costs through subsidies. Costs are low, especially if dual purpose park-and-ride lots are used. | Transit authority must administer program. | Sound planning and integration is required to develop public acceptance. | |
| Paratransit | Increases non-auto options. Increases options of mobility limited people. | Public or private sectors bear costs depending on the individual tactic. | Administrative agency is required. | Public acceptance potential may be limited. | Legal changes at the interface of public-private transportation may be required. |
| Congestion Reducing and Modal Choice Oriented Strategies | | | | | |
| Parking Management | Detrimental to auto mobility. | Public and private sectors share the cost burden. Costs are fairly low. | City must administer program. | Impacts are limited because of private ownership of parking lots and different types of lots. | Legislative action is usually required. |
| Pricing | Detrimental to auto mobility. | Public and private sectors bear costs differently, depending on the tactic. | Pricing as implemented and administered would differ from from marginal cost pricing. | Pricing tends to be unpopular and political resistance is likely. | Legislative action is required. |

# CHAPTER 6

## ANALYSIS OF THE IMPLICATIONS FOR MODELING TSM STRATEGIES

As a basis for developing recommendations for Phases II and III, an analysis of the implications for modeling each of the TSM strategies is now considered. This analysis is organized according to the models comprising the sequential urban travel modeling process and inputs to these models. The relationship of these models, and their general functions, are shown in Figure 5.

Table 6, which follows the general format of Figure 5, shows for each model or set of model inputs the implications for modeling TSM strategies. For example, consider item 1.1, revision of network coding for specific links. Modeling of the strategies related to traffic operations and signalization, parking management, transit operations and commercial vehicles would involve revising travel times, turn penalties, parking indexes and capacities for individual links and nodes.

In reviewing Table 6, it becomes clear that most TSM strategies have a major impact on transportation network representation, modal choice and trip assignment. The strategy implications for trip generation and distribution models, and inputs to these models, are more selective. It is these latter strategies, however, that are most effective in terms of modifying travel behavior, since they do affect

FIGURE 5

SEQUENTIAL URBAN TRAVEL MODELLING PROCESS

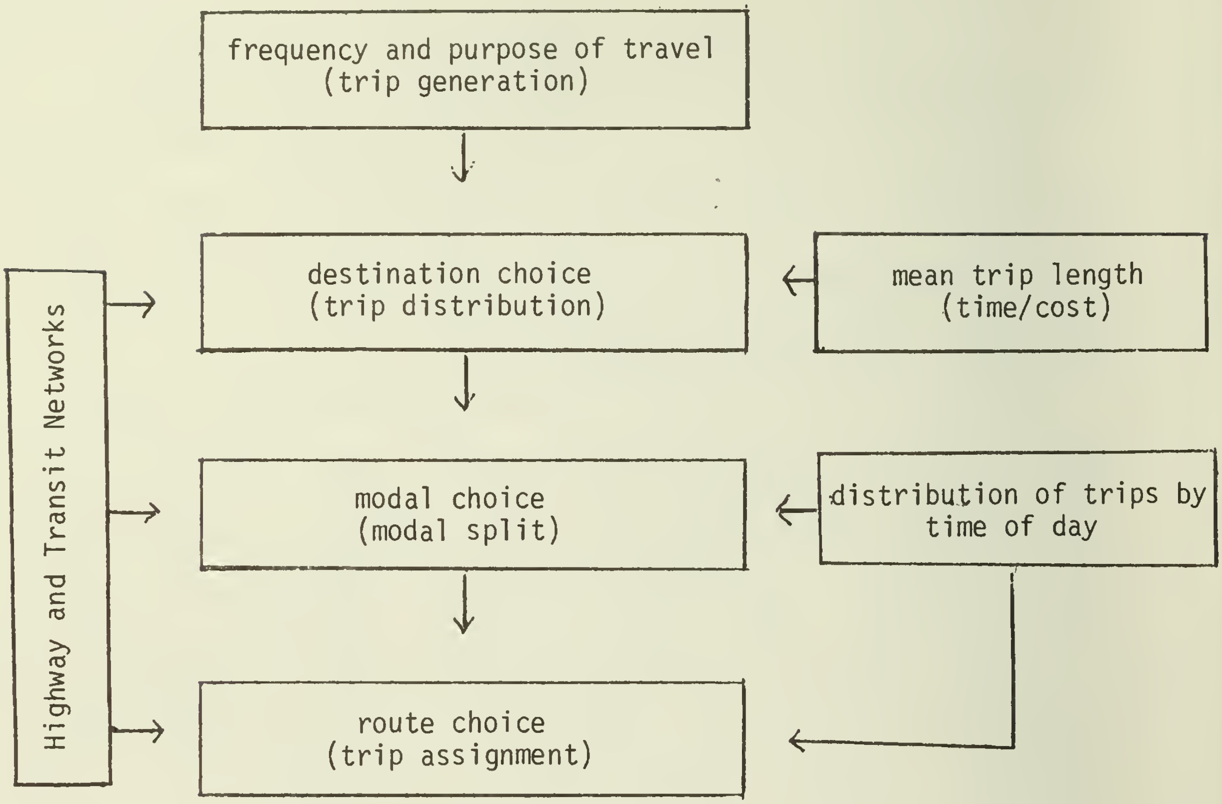


TABLE 6

IMPLICATIONS OF TSM STRATEGIES FOR MODELING URBAN TRAVEL

1. Highway and Transit Network Representation
    1. Revision of network coding for specific links
        1. traffic operations and signalization
        2. commercial vehicles
        3. transit operations
        4. parking management
    2. Addition of a route, facility, type of service or modification of a portion of the network
        1. roadway assignment
        2. route diversion
        3. transit operations and management
        4. intermodal coordination
        5. paratransit
    3. Reconsideration and extension of access and egress functions including concept of an integrated network
        1. intermodal coordination
        2. pedestrians and bicycles
        3. parking management
    4. consideration of representation travel cost as well as time on each link in a more systematic manner, including peak and off-peak specific costs
        1. parking management
        2. pricing

5. improvement of congestion or capacity restraint functions possibly providing for different functions for peak and off-peak periods

    1. commercial vehicles
    2. traffic operations and signalization
    3. roadway assignment
    4. route diversion
    5. parking management
    6. pricing

2. Inputs to Travel Models

    1. Changes in mean trip length measured in time or cost

        1. roadway assignment
        2. route diversion
        3. paratransit
        4. pricing

    2. Major changes in time-of-day of travel affecting ratio of peak-hour to 24-hour flows

        1. commercial vehicles
        2. work schedule changes
        3. route diversion
        4. pricing, if congestion of peak-period oriented

3. Trip Generation Model

    1. Effect on number of work and non-work trips

        1. work schedules
        2. paratransit
        3. pricing

4. Trip Distribution Model

1. Effects of travel cost as well as time on ordering of destination zones in intervening opportunities model (possible need to use generalized cost function involving transit and highway networks as basis for zonal ordering in model)

    1. roadway assignment

    2. route diversion

    3. intermodal coordination

    4. pricing

2. need to extend basis for calibration of trip distribution model from time to time-cost

    1. roadway assignment

    2. paratransit

    3. pricing

5. Modal Split Model

    1. Expansion of number of transit modes represented and use of one-step vs. two-step modal split process

        1. pedestrians and bicycles

        2. roadway assignment

        3. intermodal coordination

        4. paratransit

    2. Reliability of modal split model parameters in context of substantial time-cost or network modifications including relative weighting of times and costs

        1. pedestrians and bicycles

        2. roadway assignment

        3. route diversion

        4. transit operations

        5. intermodal coordination

        6. paratransit

        7. parking management

        8. pricing

    3. Ability of present model structure to represent service or functional changes

        1. work schdeules--effect of flexi-time and four day week on ride sharing

        2. paratransit--determination of travel time for demand-responsive modes

6. Trip Assignment Model

    1. Use of an assignment procedure well-suited for networks with several paths of equal time-cost between origin-destination pairs (equilibrium assignment)

        1. traffic operations and signalization

        2. commercial vehicles

        3. roadway assignment

        4. route diversion

        5. intermodal coordination

        6. parking management

        7. pricing

    2. Use of peak vs. off-peak assignment

        1. traffic operations and signalization

        2. commercial vehicles

        3. work schedules

        4. roadway assignment

        5. route diversion

        6. transit operations and management

        7. paratransit

8. parking management
9. pricing

the frequency of trips, destination choice and trip length. Of course, these are the items that are also most difficult to model.

Several of these modeling issues require additional discussion beyond the brief account in Table 6. These are:

1. peak vs. off-peak travel estimates
2. generalized time-cost and composite time-costs
3. regionwide mean travel time-cost
4. equilibria problems

<u>Peak vs. Off-peak Travel Estimates</u>

Vehicle emissions associated with peak period vehicle flows (mainly excess carbon monoxide concentrations in corridors) may be reduced in part by changing the time at which trips are made. A variety of TSM strategies, including work schedules, pricing and route diversion, are oriented to this objective. At present, CATS models, as well as those of most other metropolitan planning organizations, estimate travel on a 24-hour weekday basis. Peak-hour flows are determined by scaling 24-hour flows by the ratio of peak-hour to 24-hour flows for each facility type. Clearly, results of this estimation procedure will not be highly sensitive to strategies defined on the

time-of-day. In contrast, time-of-day may not be a significant factor for oxidant related emissions which are more sensitive to total travel throughout the day.

The implications of modeling vehicle flows by peak and off-peak periods are rather profound. A more detailed time stratification is well beyond the present modeling practice, both in terms of model development and cost. The inherent difficulties of incorporating into models strategies which are strongly related to time-of-day need to be considered, together with the implementation feasibility of such strategies, in determing the work program for Phases II and III.

## Generalized Time-Cost and Composite Cost

A modeling item that affects all levels of the sequential process concerns the manner in which travel costs are treated in relation to travel time. This item affects not only the pricing strategy, but other strategies that would alter the present relationship of travel time and cost, such as parking management, route diversion and intermodal coordination.

The usual way of attacking this problem is to convert time and cost into a common unit, as is presently done in CATS modal choice model. This common unit of metric is called generalized time-cost. This procedure should be extended to trip distribution and assignment in order to

represent better the travel conditions facing tripmakers in choosing destinations and routes. Moreover, the time and cost of transit trips shoud be reflected in the trip distribution model along with highway costs. This can be accomplished by utilizing some recent research results for defining a composite cost of travel over highway and transit.

While these time and cost transformations are conceptually simple and relatively straightforward to implement, the question of model performance remains. Effort should be devoted in Phases II and III to evaluating the goodness-of-fit of these revised models.

### Regionwide Mean Travel Time-Cost

An item related to the construction of a time-cost function that suitably reflects the deterrence or disutility of travel concerns determining the mean of the time-cost function for the region for a given set of TSM strategies and other conditions. The regionwide mean of generalized time-cost is used as the basis for calibrating the trip distribution model, and is logically regarded as an external input to that model. This is particularly necessary if the trip distribution model is to be responsive to substantial changes in travel cost and time that might be imposed by TSM strategies such as pricing, roadway assignment, and parking management.

The change in the regional distribution of travel time-cost, and therefore the mean time-cost, in response to a transportation system change is very poorly understood for a number of reasons. Foremost among these is the fact that there is no reliable continuing data base on trip length. Until recently, the only data were from home interview origin-destination studies conducted on a one-time basis. In 1975-76 a limited survey (15,000 households) was conducted in the Chicago region and 20 other metropolitan areas; this data will provide a basis for estimating perceived travel time.

A second difficulty is the problem of inferring whether observed changes in mean travel time-cost actually result from TSM, or from other policies. Many other forces are at work in the region that may influence trends in trip length including migration, ongoing relocation of employment and residences, changes in the relation of the overall cost of living to income, and social and ethnic factors.

Some effort to address these questins, however, should be made. Ways of tracing trends in trip length indirectly through gasoline consumption and vehicle registrations should be pursued, if only to determine the direction of trends. Thus, a modest investigation of this question is proposed for Phases II and III.

## Equilibria Problems

A central feature of the sequential modeling process is the use of capacity restraint functions relating link travel time to link flows. A simpler type of capacity restraint applies to parking space availabilty. In order to determine link travel times at any stage in the modeling process, link flows must be known. But these flows are the variable to be determined by the models. Thus a circularity exists in the solution of the process; in reality the process is cyclic, not sequential.

Approximate procedures have been used by CATS and other metropolitan planning organizations to obtain approximate solutions to this problem with regard to trip assignment. Rarely, if ever, have link travel times reflecting congested conditions been used in the trip distribution and modal choice models.

During the past few years, an equilibrium assignment procedure for solving this circularity in the trip assignment model has been implemented with considerable success by a few planning agencies. Recently, the procedure has been tried at CATS on an experimental basis. The equilibrium assignment method has the following desirable behavioral attribute: if more than one route is used to travel from an origin to a destination, then each route which is used has the same time-cost; no unused route has a lower cost.

The equilibrium assignment method seeks this solution in

an iterative fashion which closely parallels other assignment methods in its general approach. The method converges to a satisfactory level in about four iterations; thus, it requires an amount of computational effort similar to conventional approaches.

Equilibrium assignment will be important for modeling any TSM strategy which has a major effect on route choice such as roadway assignment, route diversion, traffic operations and traffic signalization.

In principle, the same equilibrium problem applies to trip distribution and modal choice. These problems can be solved heuristically by using the results of the equilibrium assignment to resolve the trip distribution and modal choice models as indicated by the feedback arrow in Figure 5. However, such a model is not guaranteed to converge to equilibrium. Convergent models have been developed and tested, but their use would imply wholesale revisions in CATS modeling process which seem inappropriate to pursue as a part of this effort. The effect of this general problem on the quality of flow estimates should be addressed as a part of Phases II and III in order to determine the extent to which the behavioral assumptions of the models are met.

# CHAPTER 7

# RECOMMENDATIONS

This chapter presents a summary of recommendations for research activities which will be completed in Phases II and III of this project. The recommendations which follow are based on three analyses performed in earlier portions of this report: (a) effects of individual TSM strategies on vehicle emission reduction; (b) technical feasibility and public acceptability; and (c) modeling capability. The conclusions of each of these analyses have been synthesized to determine a joint ranking for each strategy. The strategies ranked are those shown in Table 7.

The emissions-reduction potential of TSM strategies is ranked high, medium and low. To achieve a high ranking, a strategy must have the potential of substantial reductions in vehicle flows in a specific area. Only the pricing, route diversion and paratransit are judged to have this potential.

At the other extreme, strategies oriented toward improving the operation and management of highway and transit systems are judged to be ineffective in reducing emissions. Although such service and management strategies may relieve congestion locally, reduced emissions from these improvements tend to be offset by increased travel volumes and diversion of traffic into the improved area.

TABLE 7

RANKINGS OF TSM STRATEGIES

Technical Feasibility and Public Acceptance

| Emissions Reduction Potential | LOW | MEDIUM | HIGH |
|---|---|---|---|
| HIGH | Pricing (2) | Route Diversion (2)<br>Paratransit (2) | |
| MEDIUM | | Commercial Vehicles (3)<br>Roadway Assignment (2)<br>Intermodal Coordination (2)<br>Parking Management (3)<br>Work Schedules (3) | |
| LOW | | | Traffic Operations (1)<br>Traffic Signalization (1)<br>Pedestrians & Bicycles (1)<br>Transit Operations (1)<br>Transit Management (1) |

Modelling difficulty shown in parentheses after each strategy
(1) - relatively straightforward
(2) - feasible
(3) - infeasible or very difficult

Each strategy is ranked according to its technical and political feasibility across the top of the table from low to high. Low feasibility rankings are assigned to strategies that strongly inhibit mobility, are technically very difficult to implement, or both. High feasibility rankings are assigned to strategies that increase mobility and are technically easy to implement.

A third ranking with respect to difficulty of modeling is shown in parentheses after each strategy. Relatively straightforward modeling tasks are shown as (1). Infeasible or very difficult modeling tasks are shown as (3).

A brief discussion follows of the groupings that appear in Table 7. Note that the strategies group together in a diagonal fashion from high emissions-reduction potential and low feasibility (pricing) to low emissions-reduction potential and high feasibility (highway and transit system improvements). Note also that the difficulty of modeling decreases from upper left to lower right.

Two strategies lie off the main diagonal. Route diversion and paratransit are similar to pricing in emissions-reduction and modeling difficulty, but they are regarded as somewhat more feasible to implement.

The strategies in the center of Table 7 have moderate potential to reduce emissions and are moderately feasible to implement and to model. To a large extent, this is the group of strategies identified by the Scope of Work for

Phase III. It is recommended that this set of strategies be studied in an integrated manner.

A second set of strategies concerns highway and transit system operations and management. These strategies are readily implemented, but have relatively less potential for reducing emissions. It is important to undertake some modeling activities concerning this set of strategies for several reasons. First, many improvements of this type are implemented each year, so it is useful to try to determine their effect on the system. Second, there is some evidence that such improvements increase emissions, at least locally. It seems important to try to model whether or not there are corresponding decreases elsewhere. Third, there are a number of points where improvements in traffic and transit operations, especially transit, complement intermodal coordination and paratransit strategies. Fourth, it is useful to have a reference set of strategies against which to compare the strategies concerned with parking and ride sharing.

To these system operations and management strategies will be added route diversion and commercial vehicles. Route diversion and commercial vehicle strategies operate on a scale similar to operations and management strategies. Route diversions have a higher potential to reduce emissions because of the limitations they impose on the behavior of trip makers. All six of these strategies tend to focus on

route choice and/or modal choice; therefore, they seem to form a logical group to study together as Phase II of the research (Table 8).

Several of the strategies recommended for Phases II and III involve elements of a pricing approach. For example, area-wide licensing schemes, reduced transit fares, toll-free lanes for high occupancy vehicles, and low parking rates for high occupancy vehicles are all elements in a comprehensive pricing policy. These types of pricing schemes will be incorporated in the modeling efforts of Phases II and III whenever appropriate.

Recommended for exclusion from further study are pedestrians and bicycles and regional pricing strategies, such as congestion pricing and gasoline taxes, and parking price changes which vary significantly by time of day. The latter are not susceptible to effective modeling at this time.

Work schedule changes are also not recommended because the difficulty of modeling appears to be far beyond the present generation of models with respect to the effect of travel by time-of-day.

Another minor work element is recommended for Phase II that transcends the above set of categories. This concerns the effect of pricing-related strategies on the regional mean time-cost of travel. In this regard, it is proposed to examine whether there are any secondary data that might

enable an estimate of the price elasticity of mean trip length to be made.

With regard to the groups of strategies referred to above as Phases II and III, a package of models and procedures building on CATS modeling capability will be assembled. These models will be tested on prototype examples of each of the TSM strategies under study. The resulting models will provide a capability for analyzing the sets of TSM strategies listed in Table 8.

An ongoing effort will be made to explore the feasibility of implementing each strategy based on technical and political experience in other urban areas. This material will be included in the final report.

TABLE 8

RECOMMENDED STRATEGIES FOR PHASES II AND III

1. Phase II
    1. Traffic Operations
    2. Traffic Signalization
    3. Commercial Vehicles
    4. Route Diversion
    5. Transit Operations
    6. Tranist Management
2. Phase III
    1. Roadway Assignment
    2. Intermodal Coordination
    3. Paratransit
    4. Parking Management
    5. Pricing

# GLOSSARY

access function--a measure of the difficulty (time-cost) of getting to the line haul portion of the trip.

ambient air quality standards--the ambient airbourne concentration of pollutant prescribed by law that cannot be exceeded during a specified time in a prescribed area.

area strategy--a collection of tactics that tend to impact at an area or regional scale.

capacity restraint (congestion) function--a mathematical fuction relating highway speed to the number of vehicles on the road.

composite time cost--the combined generalized time-cost for two or more modes.

corridor strategy--a collection of tactics that end to impact at a transportation corridor or limited area scale.

demand responsive transit--transit characterized by flexible routing and scheduling of relatively small vehicles to provide door-to-door or point-to-point transportation at the user's demand.

egress function--a measure of the difficulty (time-cost) of getting from the line haul portion of the trip to the final destination.

equilibrium assignment--a trip assignment for which the generalized time-costs over all used routes are equal and for which no unused route has a lower time-cost for all origin-destination pairs. This procedure allows for the selection of alternative routes.

fixed route transit--passenger transportation service that is available to any person who pays a prescribed fare and operates on established schedules along designated routes with specific stops. fixed route transit includes bus, commuter rail, and fixed guideway services.

generalized travel time-cost--a linear combination of travel time cost, and other factors which equals the total disutility or difficulty of using a transportation system between two points.

high occupancy vehicle--a passenger vehicle that carries two or more persons, e.g., a bus, carpool, vanpool.

highway (transit) network--a representation of a transportation system in which each intersection is specified by nodes and each facility joining two nodes

is called a link. Links normally are directional and have a specified travel time, distance, and cost.

mean speed--the average speed of all vehicles operating in the transportation system for a defined time period or point in time.

metropolitan planning organization--the designated organization responsible for the coordination of all TSM planning efforts within a designated metropolitan region.

modal choice (split)--the proportion of total person-trips that uses each of various specified modes of transportation.

modal choice (split) model--a procedure for estimating the proportion of trips from an origin to destination zone using each of various specified modes.

nonattainment area--an area in which airbourne concentrations of pollutants exceed primary or secondary air quality standards.

peak-period--the period of time, usually in the morning or afternoon, in which the maximum amount of travel occurs.

primary air quality standards--the ambient airbourne

concentration of pollutants prescribed by law as being necessary for protecting the public health.

regionwide mean travel time-cost--the mean travel time-cost for all trips in the region.

secondary air quality standards--the ambient airbourne concentration of pollutants prescribed by law as being necessary for protecting the public welfare.

strategy--a collection of TSM tactics which are similar in nature.

tactic--an individual TSM action.

time cost--the perceived difficulty of travel time and money.

transportation systems management--a planning strategy which identifies transportation projects which are generally low-cost and can be implemented relatively quickly. Chosen projects are then scheduled for implementation in the transportation improvement program.

travel cost--the expenses incurred in making a trip, including both out-of-pocket and other less obvious costs, such as maintenance and depreciation costs, to the individual traveler.

travel demand modeling--a set of procedures for estimating

the flow of vehicles and persons on each link for a typical weekday normally involving trip generation, distribution, modal choice and assignment.

travel time--the time duration of a trip from the point of origin to the final destination, including waiting and walking time at trip ends and transfer points.

trip (route) assignment model--a procedure for determining the route over the transportation network taken by trips from one zone to another.

trip distribution model--a procedure for estimating the number of trips from one zone to another.

trip frequency--the number of vehicles traveling in the transportation system at a given time.

trip generation model--a procedure for estimating the number of trips beginning and ending in each zone, usually by trip purpose.

trip length--the distance traveled on a trip from the point of origin to the final destination, including walking distance at trip ends and at transfer points.

vehicle emissions modeling--the procedure for estimating and projecting motor vehicle produced emissions for specified regions or road systems.

vehicle miles traveled--the movement of one vehicle a distance of one mile (1.61 kilometers).

REFERENCES

1. Alan M. Voorhees and Associates (1973) An Analysis of the Economic Impact of Motor Vehicle Use Restrictions in Relation to Federal Ambient Air Quality Standards, Springfield, Virginia.

2. Alan M. Voorhees and Associates and Ryckman, Edgerly, Tomlinson and and Associates (1971) A Guide for Reducing Automotive Air Pollution, Environmental Protection Agency, Washington, D.C.

3. Alan M. Voorhees and Associates (1974) Guidelines to Reduce Energy Consumption, Washington, D.C.

4. Alan M. Voorhees and Associates (1974) A Report on TSM Institutional and Planning Research. Chapter 4: TSM Action, Interaction and Impact, draft, Urban Mass Transportation Administration, Washington, D.C.

5. Association of Bay Area Governments, Bay Area Air Pollution Control District and Metropolitan Transportation Commission (1977) Environmental Management Plan for the San Francisco Bay Region. Draft, Air Quality Maintenance Plan, San Francisco, Calif.

6. Central Transportation Planning Staff (1977) Transportation Systems Management Element of the Transportation Plan and Program for the Boston Region, Metropolitan Planning Organization, Boston, Massachusetts.

7. Chicago Area Transportation Study (1978a) An Analysis of Six TOPICS Intersection Improvements in Northeastern Illinois, draft, Chicago, Illinois.

8. Chicago Area Transportation Study (1978b) The Transportation System Management Plan for Northeastern Illinois, Chicago, Illinois.

9. Demetsky, J., and Parker, M. R., Jr. (1978) "The Role of Parking in Transportation Systems Management." Transportation Research Board, Washington, D.C.

10. U. S. Department of Transportation (1975) "Transportation Improvement Program." Federal Register, Vol. 40, No. 181, Part II, pp. 42976-42984.

11. Dern, J., et. al., (1976) Parking Management Strategies for Reducing Automobile Emissions, U. S. Environmental Protection Agency, Washington, D.C.

12. DiRenzo, J. F. "An Assessment of Immediate Action Travel Reduction Strategies for Achieving Air Quality and Energy Conservation Objectives." Paper presented at the Intersociety Conference on Transportation, Atlanta, Georgia, July 15-18, 1975.

13. Gakenheimer, R. and Meyer, M. (1977) Transportation Systems Management; Its Origins, Local Response and Problems as a New Form of Planning, Washington, D.C.

14. GCA Corporation (1975) Evaluation of Transportation Control Strategies for Chicago. Final Report, U. S. Environmental Protection Agency, Washington, D.C.

15. Gilman, R. H. (1971) "The Impact of Staggered Work Hours on Public Transportation." New Approaches to Urban Transportation Needs, American Society of Civil Engineers, New York.

16. Goeller, B. F. et. al. (1973) San Diego Clean Air Project: Summary Report, County of San Diego, Calif.

17. Harkness, C. (1973) Telecommunications Substitutes for Travel: A Preliminary Assessment of their Potential for Reducing Urban Transportation Costs by Altering Office Location Pattern, Ph.D. Dissertation, University of Washington, Seattle, Washington.

18. Heath, D. (1973) "What's Coming in City Parking?" Nation's Cities, Jan. 1973, p. 18.

19. Horowitz, J. (1976) Transit Requirements for Achieving Large Reductions in Los Angeles Area Automobile Travel, U.S. Environmental Protection Agency, Washington, D.C.

20. Illinois, State of, Environmental Protection Agency (1977) Recommended Illinois Designations Attainment/Non-Attainment Pursuant to Sec 107(D)(1) of the Clean Air Act, as Amended, Springfield, Illinois.

21. Institute of Public Administration and Teknekron, Inc. Evaluating Transportation Controls to Reduce Motor Vehicle Emissions in Major Metropolitan Areas, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina (1972).

22. INTERPLAN Corporation (1975) Joint Strategies for Urban Transportation, Air Quality and Energy Conservation. Volume 1: Joint Action Programs, Urban Mass Transportation Administration and U.S. Environmental Protection Agency, Washington, D.C.

23. INTERPLAN Corporation (1977) TSM: State of the Art, Urban Mass Transportation Administration, Washington, D.C.

24. JHK and Associates (1977) Measures of Effectiveness for Multimodal Urban Traffic Management. Working Paper 1. Review of Selected Traffic Management Schemes, Federal Highway Administration, Washington, D.C.

25. JHK and Associates (1978) Measures of Effectiveness for Multimodal Urban Traffic Management. Working Paper 7. Recommended Measures of Effectiveness for TSM Tactics, Federal Highway Administration, Washington, D.C.

26. JHK and Associates and Fredrick A. Wagner (1978) Evaluation of Carpool Demonstration Projects. Interim Report, Federal Highway Administration, Washington, D.C.

27. Kirby, F. et.al. (1974) Para-transit Program Design: Neglected Options for Urbn Mobility. Final Report, U.S. Department of Transportation, Washington, D.C.

28. Kulash, D. (1973) Parking Taxes for Congestion Relief: A Survey of Related Experience, draft, The Urban Institute, Washington, D.C.

29. Los Angeles Local Agencies Tas Force (1973) "Clean Air": The Local Agencies Plan for the L. A. Air Basin, Los Angeles, Calif.

30. Mierzejewski, A. "The Economics of Transportation Control Strategies for Reducing Air Pollution," Traffic Engineering, pp. 22-28.

31. Orski, C. K. (1972) "Car-Free Zones and Traffic Restraints: Tools of Environmental Management." Pedestrian Protection, (Highway Research Record 406) Highway Research Board, Washington, D.C., p. 37-45.

32. Peat, Marwick, and Mitchell and Company (1978a) Air Quality Impacts of Transit Improvements, Preferential Lane, and Carpool/Vanpool Programs, U. S. Environmental Protection Agency, Washinton, D.C.

33. Peat, Marwick, and Mitchell and Company (1978b) An Assessment of Immediate Action Travel Reduction Strategies for Achieving Air Quality and Energy Conservation Objectives, Atlanta, Georgia.

34. Peat, Marwick, and Mitchell and Company (1978c) 34. Preferential Lane and Carpool Programs, An Annotated Bibliography of Demonstration and Analytical Experience, U. S. Environmental Protection Agency, Washington, D.C.

35. R. H. Pratt Associates, Inc. (1973) Low Cost Urban Transportation Alternatives: A Study of Ways to Increase the Effectiveness of Existing Transportation Facilities. Vol. I: Results of a Survey and Analysis of 21 Low Cost Techniques, U. S. Department of Transportation, Washington, D.C.

36. R. H. Pratt Associates, Inc. (1976) Transportation Controls for Air Quality Improvement in the National Capital Region. National Capital Region Transportation/Air Quality Study, Washington, D.C.

37. Pratt, R. H., Pederson, N. J., and Mather, J. J. Traveler Response to System Changes: A Handbook for Transportation Planners, Federal Highway Administration, Washington, D.C. (1977).

38. Simkowitz, H. (1978) A Comparative Analysis of Results from Three Recent Non-Separated Concurrent-Flow High Occupancy Freeway Lane Projects: Boston, Santa Monica and Miami, U. S. Department of Transportation Systems Center, Cambridge, Massachusetts.

39. System Design Concepts, Inc. (1977) Operating Multi-Modal Urban Transportation Systems, U. S. Department of Transportation, Washington, D.C.

40. System Design Concepts Inc. (1978) Transportation Systems Management Planning and Institutional Arrangements. Case Studies: Cincinatti, Pittsburgh, San Antonio, San Diego, and Washington, D.C. Final Report, Urban Mass Transportation Administration, Washington, D.C.

41. Thomson, J. M., et al. (1974) "Is Traffic Limitation Feasible?" in Proceedings of the International Conference on Transportation Research, Transportation Research Forum, Chicago, Illinois.

42. Transportation Research Board (1977) Transportation System Management, Special Report 172, Washington, D.C.

43. TRW Transportation and Environmental Operations (1972) Predictions of the Effects of Transportation Controls on Air Quality in Major Metropolitan Areas, U. S. Environmental Protection Agency, Research Triangle, North Carolina.

44. TRW Transportation and Environmental Operations (1972) Transportation Control Strategy Development for the Metropolitan Los Angeles Region, Environmental Protection Agency, Research Triangle, North Carolina.

45. U. S. Environmental Protection Agency (1978) "National Ambient Air Quality Standards. States

Attainment Status." Federal Register, Vol. 43, No. 43. Part II, pp.8962-9059.

46. Weiner, F. and Poole, B. (1974) Some Urbanized Area Journey to Work Statistics 1970, U. S. Department of Transportation, Washington, D.C.